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Study 27**

**Mineralization in
Diatreme Structures
North of Lake Superior**

**by
R.P. Sage**

1982



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Conversion Factors for Measurements in Ontario Geological Survey Publications

If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL

SI Unit	Multiplied by	Gives
1 mm	0.039 37	inches
1 cm	0.393 70	inches
1 m	3.280 84	feet
1 m	0.049 709 7	chains
1 km	0.621 371	miles (statute)

CONVERSION FROM IMPERIAL TO SI

Imperial Unit	Multiplied by	Gives
LENGTH		

1 inch	25.4	mm
1 inch	2.54	cm
1 foot	0.304 8	m
1 chain	20.116 8	m
1 mile (statute)	1.609 344	km

AREA

1 cm ²	0.155 0	square inches	1 square inch	6.451 6	cm ²
1 m ²	10.763 9	square feet	1 square foot	0.092 903 04	m ²
1 km ²	0.386 10	square miles	1 square mile	2.589 988	km ²
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha

VOLUME

1 cm ³	0.061 02	cubic inches	1 cubic inch	16.387 064	cm ³
1 m ³	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m ³
1 m ³	1.308 0	cubic yards	1 cubic yard	0.764 555	m ³

CAPACITY

1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	4.546 090	L

MASS

1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	31.103 476 8	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	0.453 592 37	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	907.184 74	kg
1 t	1.102 311	tons (short)	1 ton (short)	0.907 184 74	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	1016.046 908 8	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	1.016 046 908 8	t

CONCENTRATION

1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE—Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in cooperation with the Coal Association of Canada.

ABSTRACT

A number of intrusive breccia bodies situated north of Lake Superior have been classified as diatremes or explosion breccias. The Gold Range breccia located near Schrieber, Ontario, is a relatively small body and appears to be related to the emplacement of a lamprophyric intrusion. The similarly small Neys diatreme is located within the Port Coldwell alkalic complex and is likely a high level feature related to the emplacement of this alkalic rock pluton. Neither the Gold Range nor the Neys structure has any apparent economic mineralization.

The Slate Islands diatremes consist of many ramifying breccia dikes. The Slate Islands breccias display evidence of alkalic rock-carbonatite magmatism, and display shock metamorphic features. No economic mineralization has been reported in the Slate Islands diatremes.

The McKellar Creek and Dead Horse Creek structures are extensively altered and have uranium, thorium, and beryllium mineralization. The anomalous concentrations of rare earths, niobium, phosphorous, and titanium and the type of alteration (hematization, silicification, and potassic metasomatism) of these two structures are interpreted by the author to indicate an alkalic rock-carbonatite affinity. These two complexes are considered by the author to be coeval in age and origin. The mineralizing fluid is thought to be a distal fenitizing solution, and the more intense the alteration the more intense the mineralization.

The uranium, thorium, and beryllium mineralization appears to be concentrated towards the margins of the diatreme structures and possibly in radiating and/or marginal shear zones. Both the McKellar Creek and Dead Horse Creek structures present interesting exploration targets; the larger, more altered Dead Horse Creek structure is the more favourable.

The Slate Islands, McKellar Creek, and Dead Horse Creek structures are related to major faulting of the Lake Superior basin. Prospecting along the extension of fault zones, related to the development of the Lake Superior basin and the alkalic rock-carbonatite petrogenetic province north of the basin, will likely uncover additional breccia structures. In view of the possible carbonatite-kimberlite-diatreme relationship, prospectors working in this region should keep a discerning eye open for rocks of a kimberlitic nature.

The Gold Range, Neys, McKellar Creek and Dead Horse Creek diatremes appear to be Late Precambrian in age and related to alkalic rock magmatism of that period. On the basis of a K-Ar isotopic age of approximately 300 million years, obtained on a lamprophyre dike of carbonatite affinity which is cut by breccia dikes, the Slate Island diatremes are post-Pennsylvanian in age.



Mineralization in Diatreme Structures

North of Lake Superior

by
R.P. Sage¹

INTRODUCTION

In 1976, radioactive intrusive breccias were discovered near the west flank of the Port Coldwell alkalic complex by prospectors working for Gulf Minerals Canada Limited. The discovery of other radioactive showings within intrusive breccias of the area has stimulated uranium exploration in the region. Mapping of the Slate Islands and alkalic rock-carbonatite complexes within Ontario by the author (Sage 1974, 1975, in preparation), showed that diatreme structures occur within the same tectonic and petrologic setting as alkalic rock-carbonatite complexes; as a result, the Ontario Geological Survey undertook a program of investigating a number of diatreme structures north of Lake Superior. With the possible exception of the Gold Range diatreme, the diatreme structures investigated can be considered as one feature of the much larger alkalic rock-carbonatite petrogenetic province located north of Lake Superior, dominated or related directly to the evolution of the Lake Superior basin and mid-continent gravity high. Figure 1 indicates the locations of the five diatremes discussed in the text.

ACKNOWLEDGMENTS

The cooperation and operational assistance of A. Haas, B. Scott, P. McDonald, R. Denault, K. Manser, and L. Trodd, Terrace Bay District, Ministry of Natural Resources, is gratefully acknowledged. The information and assistance of A. Knapp and N. Hibbart, prospectors, and G. Pearson and T. Keil of Gulf Minerals Canada Limited is much appreciated. C. Schope assisted the author in mapping the diatreme structures during the 1978 field season. Several illustrations were prepared by B. Moore.

PHYSIOGRAPHY

The area of investigation (Figure 1) is typical of the north shore of Lake Superior. The land is rugged, heavily wooded, and contains numerous small streams and lakes.

¹Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto. Approved for publication by the Chief Geologist, Ontario Geological Survey, March 30, 1981. This report is published with the permission of E.G. Pye, Director, Ontario Geological Survey.

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FIELD MAPPING TECHNIQUE

Approximately 27 days were spent examining diatreme structures in 1978 and one day was spent in June 1979 examining the East Dead Horse subcomplex. Mapping of the Dead Horse Creek structure was plotted on acetate overlays of 1:15,840 airphotos obtained from the Airphoto Library, Ontario Ministry of Natural Resources. Traverse spacing was 120 m, using topography as control. Previous mapping (Sage 1975) was used as a base for spot-checking the Slate Islands diatremes. The Gold Range and McKellar Creek structures were mapped using pace and compass techniques. The Neys structure which had been previously mapped by Balint (1977) was briefly visited.

A spectrometer (McPhar model TV-1A) was used continuously while mapping. Readings are given as T1, T2, and T3. T1 readings include gamma counts for three radioactive elements: potassium, uranium, and thorium. T2 readings include gamma counts for only uranium and thorium, and T3 for only thorium.

During mapping, samples were routinely collected for thin section study and chemical analysis for niobium, rare earths, uranium, thorium, and beryllium.

During late 1978, Gulf Minerals Canada Limited discovered a small diatreme structure (Dead Horse East) east of the main Dead Horse Creek structure. This structure was added to the accompanying map (see Figure 10, Chart A, back pocket).

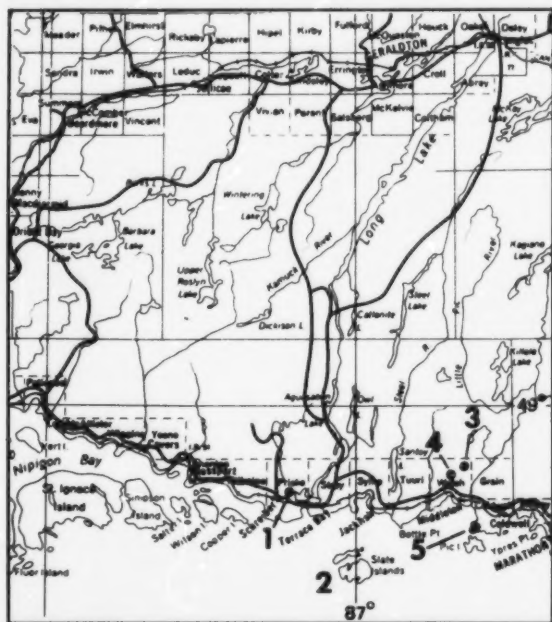


Figure 1. Location of known diatreme structures on north shore of Lake Superior. 1) Gold Range; 2) Slate Islands; 3) Dead Horse Creek; 4) McKellar Creek; 5) Neys. Scale 1:1,584,000 or 1 inch to 25 miles.

PREVIOUS GEOLOGICAL WORK

G.A. Harcourt (1938) described the Gold Range breccia and interpreted it as an explosion breccia. Walker (1967) examined the McKellar Creek breccia and interpreted it as an Aniakie conglomerate. The author visited the McKellar Creek site in 1975 and interpreted the unit as a diatreme. Mitchell and Platt (1977) prepared brief descriptions of the McKellar Creek and Dead Horse Creek structures. Balint (1977) completed a Bachelor of Science thesis, at Lakehead University, on the Neys diatreme. The author first recognized diatreme structures within this region of Lake Superior in 1974 while working on the Slate Islands (Sage 1974, 1975).

NOMENCLATURE

The author's use of the term 'diatreme' is as follows: 'A breccia-filled pipe or dike that was formed by a gaseous or fluid explosion'. Volcanic products of diatreme emplacement are not known to exist at any of the structures reported on here. No genetic connotation is implied. On the basis of field data the diatremes found along the northeast corner of Lake Superior are likely to have had several origins.

GOLD RANGE DIATREME

LOCATION AND ACCESS

The Gold Range diatreme (1 on Figure 1) is located northeast of Schreiber, Ontario. The breccia can be reached by walking north along a claim line which crosses a trail (Figure 2) leading to the west side of the Ontario Hydro reservoir located east of Schreiber. The claim line cuts the trail 660 m west of the reservoir. The breccia is 248 m north of the trail and approximately 36 m west of the claim line. Lamont Lake is located at Latitude $48^{\circ} 49'N$ and Longitude $87^{\circ} 14'W$, and the breccia is located approximately 1.6 km east of the lake.

General Geology

The breccia was first described by Harcourt (1938), who interpreted it as an explosion breccia. Harcourt (1938) described the breccia as follows:

"On claim T.B.3,411 north of the Gold Range property, an outcrop of conglomerate or pseudo-conglomerate 1 chain by 2 chains in area is apparently completely isolated from other sediments. The rock is made up of fragments of rhyolite, greenstone, iron formation, and granite, some apparently well rounded, others sharply angular. The rock is intruded by a body of lamprophyre on one side and is surrounded by grey rhyolite. A polished slab of the rock shows that the fragments are nearly all angular and that at least some of the round surfaces are due to a conchoidal fracture in the fragments. The matrix is now composed very largely of quartz and sulphides, which penetrate fractures crossing the fragments. It is conceivable that the rock is the result of explosive volcanic activity, or it may be a partially exposed lens of conglomerate".

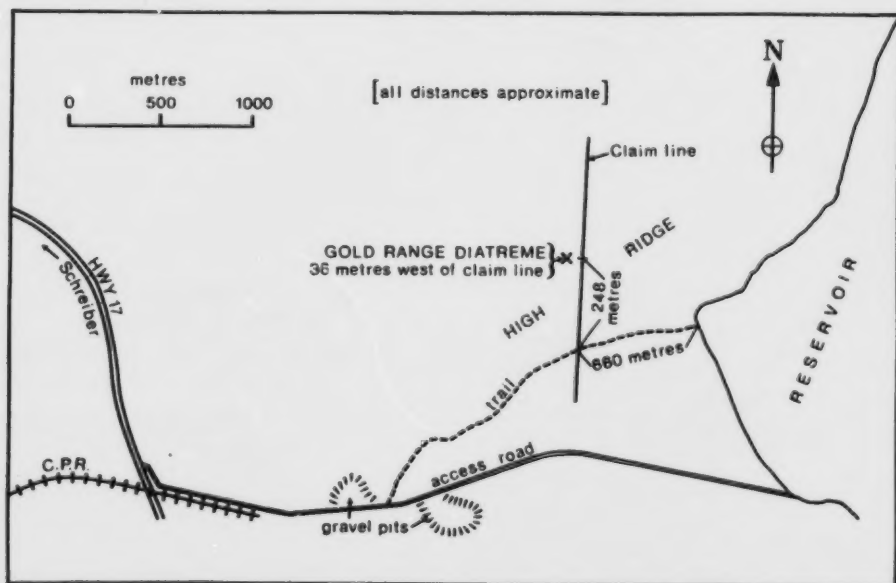


Figure 2. Sketch map of topographic features and trails in the vicinity of the Gold Range diatreme. All distances are approximate.

The author found the observations of Harcourt (1938) to be generally correct. The breccia unit (Figure 3) appears to be a little smaller (12 by 12 m) than suggested by Harcourt and conchoidal fractures were not visible in samples collected in the field. The breccia occurs at the margin of a relatively large body of biotite-rich lamprophyre which contains large inclusions of iron formation and quartz monzonite. The lamprophyre locally contains rounded blebs of carbonate and visible interstitial carbonate. The close spatial relationship of the breccia and lamprophyre suggests that the breccia may be a result of local, relatively high-level release of volatiles from the intruding carbonate-bearing lamprophyric magma. The breccia consists dominantly of angular to subangular clasts of cherty ironstone and pink fine-grained quartz monzonite. The breccia is cemented with quartz and pyrite. The pyrite also occupies fractures within the clasts.

EARLY PRECAMBRIAN

Metavolcanics

The metavolcanics enclosing the Gold Range diatreme are of two types: mafic metavolcanics, visually identified as amphibolite, which weather black, are very fine grained, and are black on the fresh surface; intermediate to felsic metavolcanics weather buff and are dark grey on the fresh surface. Both rock types are massive and are interlayered with each other, and with cherty ironstone. All metavolcanics are intruded by quartz monzonite.

One thin section was prepared from the intermediate to felsic unit. Opaque minerals are disseminated throughout. Biotite and sericite form very fine ragged grains. The micas are subparallel and impart a foliation to the rock. Epidote is locally present as very tiny grains. Plagioclase (An_{30-32}) forms anhedral interlocking aggregates.

The rock has a fine-grained, equigranular, schistose, granoblastic texture, with curved grain boundaries. Based on this one sample, the rock is of intermediate composition. Although the mineral assemblage appears to belong to the quartz-albite-epidote-biotite sub-facies of the greenschist facies of regional metamorphism (Turner 1968), the plagioclase is much more calcic than this facies generally allows. On the basis of field identification of amphibole in the mafic metavolcanics, the metamorphic grade is probably lower amphibolite facies rank rather than greenschist.

Iron Formation

The iron formation consists of interbedded very fine grained laminated grey chert and very fine grained ironstone. Iron staining is common and pyrite is visually estimated to constitute up to 10 percent of the ironstone. The ironstone and chert are complexly folded while the associated metavolcanics appear relatively undeformed. The iron formation has been prospected in numerous places by small-scale blasting. Several specimens slightly soil the finger suggesting some graphite is present, and the chert appears sacchroidal in many places. The iron formation is cut by quartz monzonite.

Quartz Monzonite

Intruding the metavolcanics and metasediments is a fine grained, pink, granitic rock. The rock is massive, pink on fresh surface, and cuts the metavolcanics in a generally ramifying pattern, but is locally crudely conformable with lithologic trends.

In thin section the rock is seen to be fine grained, massive, equigranular, and alio-trimorphic with curved to straight grain boundaries. The rock is aplitic in texture. From thin section, the rock mode is visually estimated to be 30 percent quartz, 5 percent biotite-sericite, 35 percent plagioclase (An_{32-34}) and 30 percent K-feldspar. Quartz forms an anhedral

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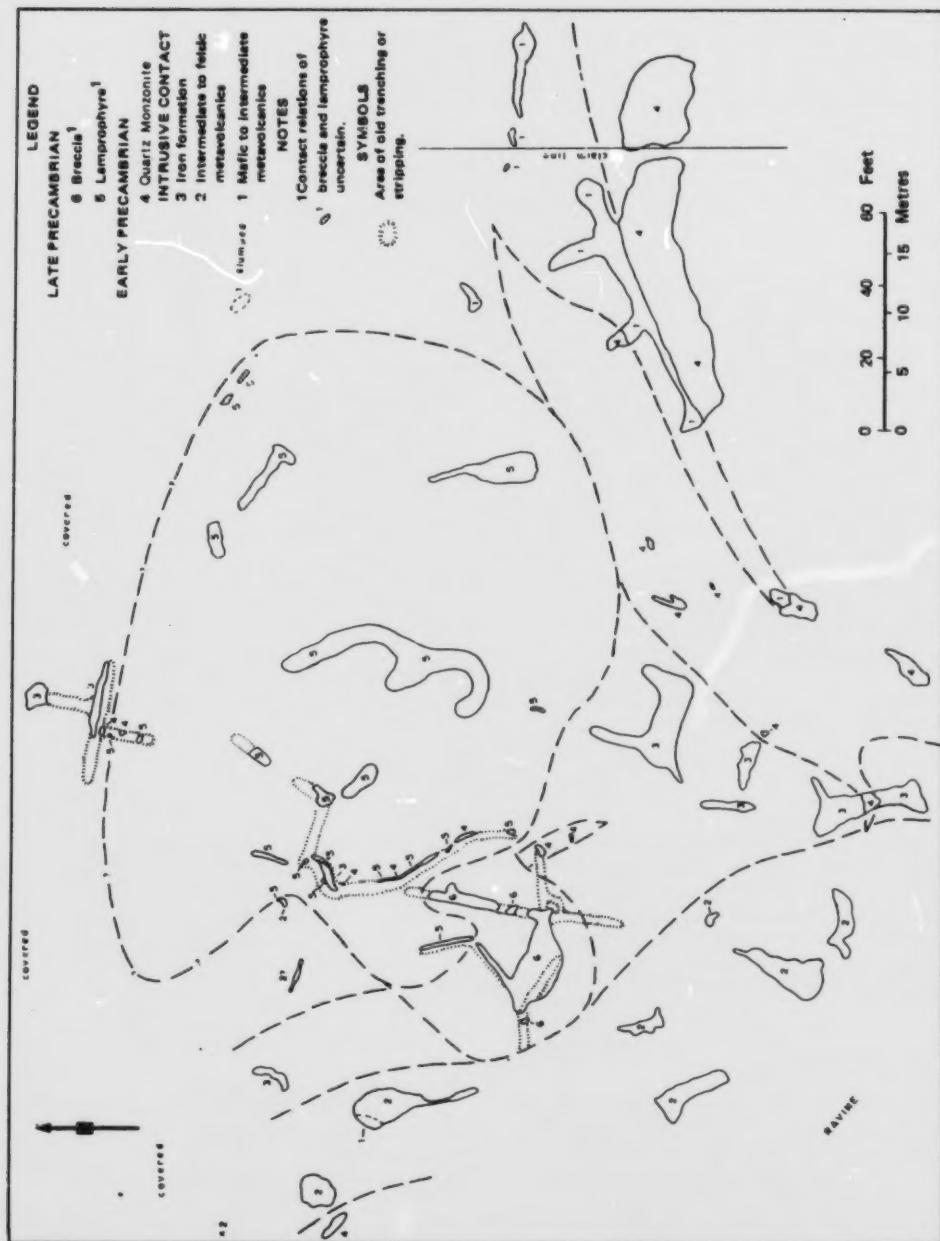


Figure 3. Geology of the Gold Range diatreme. Geology by R.P. Sage.

interlocking mosaic of grains. The micas are very fine grained interstitial grains imparting a microscopic foliation to the rock not visible in hand sample. Plagioclase is anhedral to subhedral and interlocks with the K-feldspar grains. The plagioclase is turbid and extensively saussuritized. K-feldspar is cryptoperthite to microperthite and is saussuritized along fractures. Carlsbad twinning and rare quadrille twinning of microcline is present in some grains. Some tiny sericite flecks may be poikilitically enclosed in the feldspar.

LATE PRECAMBRIAN

Lamprophyre

The Gold Range breccia is adjacent to a rock which has been classified by the author as lamprophyre. The lamprophyre body is oval shaped in plan view and elongated in a north-west-southeast direction. The rock is fine grained and weathers black. On fresh surfaces the rock is black with some pink mottling. The lamprophyre contains xenolithic blocks of iron formation, metavolcanics, and quartz monzonite. One outcrop of the lamprophyre has circular blebs of white carbonate up to 3 mm in diameter.

In thin section the rock is seen to be fine grained, massive, inequigranular-seriate, and hypidiomorphic. The fresh rock has a visually estimated mode of 35 percent biotite-phlogopite, 30 to 35 percent amphibole, 20 to 25 percent altered feldspar, 10 percent quartz, and a trace of apatite. Within the sample containing circular carbonate segregations biotite and phlogopite are the only mafic minerals.

The amphibole occurs as euhedral pale green to colourless crystals with a very fine grained unidentified alteration along fractures. The crystals are acicular and one crystal has a narrow green cap on the tip of the crystal.

The biotite-phlogopite occurs as tabular brown grains commonly with kinked and/or bent (001) cleavages. Some of the crystals have yellowish brown cores and ragged darker brown rims. The mica is subhedral in form.

Both plagioclase and K-feldspar are present. The plagioclase composition was not positively determined due to alteration but appears to be oligoclase. The K-feldspar is turbid and displays large patches of saussurite. The feldspars are clearly interstitial to the amphibole and biotite and in places poikilitically enclose these minerals.

Quartz is a late mineral. It occurs as anhedral clear grains, interstitial to the biotite and amphibole, and as interstitial grains between feldspar and the mafic minerals.

The carbonate segregations in the altered sample consist of several interlocking grains with bent rhombohedral twin planes.

The mica within the altered rock occurs as (1) tabular crystals, ragged in outline, with brown cores lighter than the rims, and (2) a fine grained micaceous groundmass. The groundmass mica is ragged and probably a breakdown product of amphibole. Outlines of the former amphiboles are evident in places. The feldspar and quartz are clearly late in the order of crystallization. Rigorous classification of the rock is not possible without further work and the author has used the term lamprophyre as a field name.

Diatreme Breccia

The Gold Range explosion breccia is heavily iron-stained and contains angular to rounded clasts of chert, metavolcanics, and quartz monzonite derived from the enclosing wall rocks. The clasts are most commonly angular, up to 5 or 6 cm in size, and are set in a quartz-pyrite matrix. Pyrite also occurs along fractures within the clasts. The pyrite content is visually estimated to be 15 volume percent.

In thin section chert is seen to occur as angular composite aggregates in which individual quartz grains display undulatory extinction and sutured grain boundaries. Sericite forms very fine grained flakes along fractures and between grains. Some of the mica is stained brown.

DIATREMES NORTH OF LAKE SUPERIOR

Chlorite, possibly after amphibole, forms aggregates with angular outlines which may be relicts of clasts derived from the enclosing metavolcanics.

Pyrite is present throughout the thin section as disseminated grains along fractures and grain boundaries.

Structural Geology

The lamprophyric body is slightly elongate in plan view with the long axis striking northwest. The long axis is parallel to the trend and extension of the Michipicoten Island fault (Hinze *et al.* 1966) that lies along the north margin of the Lake Superior basin. The Michipicoten Island fault intersects the Big Bay - Ashburton Bay fault (Hinze *et al.* 1966) near the Slate Islands which are also the site of extensive diatreme activity. It is unclear whether the Gold Range diatreme and lamprophyre are actually related to this faulting, but the author considers this a likely possibility. A linear ravine or gulley is located immediately south of the exposed breccia and lamprophyre, and may reflect the presence of shearing and/or faulting.

Economic Geology

The Gold Range structure is small, and earlier prospecting for gold evidently was not encouraging. The breccia was trenched and sampled for its gold content presumably in the 1930s (Harcourt 1938). These trenches are largely filled but sections of several can still be examined. There is no record of subsequent work.

The breccia is not radioactive as shown by the spectrometer readings taken by the author (Table 1).

A large sample of the pyrite-bearing breccia was assayed for gold and examined by 30 element spectrographic analysis. The sample returned 0.01 ounces gold per ton and the spectrographic analysis failed to detect anything of economic interest (Geoscience Laboratories, Ontario Geological Survey, Toronto).

No base metal sulphide mineralization was noted. The structure does not appear to be of significant economic interest.

**TABLE 1. AVERAGED SPECTROMETER READINGS,
GOLD RANGE DIATREME.**

Number of readings	Rock type		Average
2	Lamprophyre	T1	2500
		T2	125
		T3	38
4	Iron formation	T1	1713
		T2	105
		T3	43
5	Intermediate metavolcanics	T1	1720
		T2	100
		T3	33
3	Breccia	T1	1600
		T2	110
		T3	35
4	Quartz monzonite	T1	4120
		T2	303
		T3	66
2	Mafic metavolcanics	T1	2150
		T2	135
		T3	53

NOTES.

All readings in counts per minute.

T1 = Th + U + K. T2 = Th + U. T3 = Th.

DIATREMES NORTH OF LAKE SUPERIOR

NEYS DIATREME

LOCATION AND ACCESS

The Neys diatreme (5 on Figure 1) occurs on the shore of Lake Superior on the west side of the Coldwell Peninsula and is completely enclosed within rocks of the Port Coldwell alkalic complex. The intrusive breccia is located approximately 4.0 km south of the Neys Provincial Park headquarters and access to the breccia is possible by boat which can be launched on the Little Pic River within the park. The diatreme is located at 48°44'54''N Latitude and 86°37'58''W Longitude.

General Geology

The breccia (Figure 4) cuts coarse grained pink to reddish brown amphibole syenites that are possibly an early magmatic phase of the Pic Island intrusive subcentre of the Port Coldwell complex. This is the latest subcentre of the three comprising the Port Coldwell alkalic rock complex. These three subcentres are described in detail by Currie (1980). The syenite displays weakly developed trachytoidal texture and discontinuous streaky banding which is in part probably schlieren. The syenite is cut by alkalic, composite dikes which in turn are cut by the breccia. Mapping by Balint (1977) indicates a wedge-shaped structure 75 by 240 m in maximum dimension, pinching out landward and disappearing beneath Lake Superior towards the west. The author concurs with Balint's (1977) mapping. The breccia has a north of east trend and is likely vertically dipping. The breccia consists of rounded clasts up to several metres in size of alkalic gabbro, syenite, nepheline syenite, and amphibolite hornfels. With the exception of the hornfels, all clasts are locally derived from the alkalic rocks of the Port Coldwell complex. The amphibolite clasts may have been rafted upwards or fallen downwards. Studies by Woolsey *et al.* (1975) and McCallum *et al.* (1976) indicated that clasts derived from stratigraphically high levels may occur at structurally deep levels within any given diatreme. This results from collapse of the gas column after emplacement and from sloughing from the sides of the diatreme pipe. Along the south margin of the breccia dike is a thin dike of medium grained trachytic syenite which is up to 30 cm in width. Within the breccia and along the north contact is an irregular dike of fine grained, equigranular, reddish brown quartz-bearing microsyenite. Neither the trachytoidal syenite nor microsyenite dike cuts the enclosing coarse grained syenite. The microsyenite dike may be related to late magmatic events from the Pic Island intrusive subcentre. The matrix of the breccia consists of comminuted rock debris derived from the clasts. Minerals in the matrix are fine grained clinopyroxene, olivine, hornblende, alkali feldspar, plagioclase, and opaques (Balint 1977). Balint (1977) concluded that the matrix may have been derived from partially crystallized gabbroic material accompanying the gas during diatreme formation; a portion of it however could be comminuted rock debris resulting from milling and rounding of the alkalic gabbro clasts. Local areas of the diatreme are deeply iron stained from the oxidation of disseminated pyrite and pyrrhotite within the breccia matrix.

LATE PRECAMBRIAN

Diatreme Breccia

The Neys diatreme has recently been the subject of an extensive study by Balint (1977). The author has visited the structure and is in agreement with the mapping of Balint. Balint completed detailed petrographic studies and some chemical work on the intrusion. The following discussion is condensed from Balint (1977) with only minor alterations by the author. The author has retained the petrographic nomenclature of Balint.

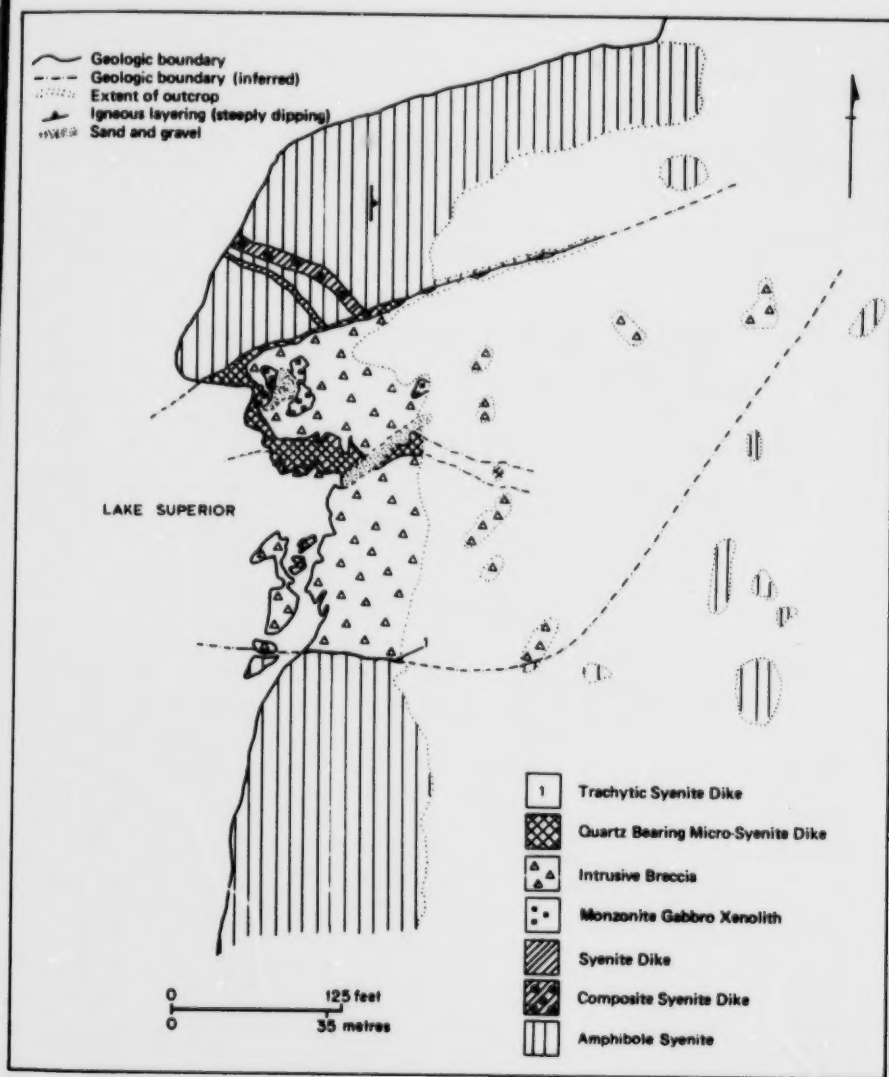


Figure 4. Geology of the Nays diatreme from Balint (1977).

DIATREMES NORTH OF LAKE SUPERIOR

The diatreme breccia displays a sharp sinuous contact with the host syenite which lacks visual evidence of alteration in proximity to the diatreme breccia (Photo 1). The intrusion is likely controlled by an as yet undefined plane of weakness.

The breccia contains clastic debris ranging from submicroscopic size to blocks 20 m on an edge. The clasts (Photo 2) consist of olivine monzogabbro, alkali feldspar syenite, nepheline syenite, and mafic hornfels. The clasts have no preferred orientation, and are angular to rounded in outline. The olivine monzogabbro clasts display a crude size zonation from north to south with the larger monzogabbro clasts found on the north flank of the diatreme.

Clast shape and size may have a bimodal distribution. Balint (1977, p.29) noted that the rounded clasts 10 to 20 cm in size are set in a finer grained comminuted aggregate of angular fragments. Rare exotic clasts of unknown origin are present.



Photo 1. Sharp contact of diatreme breccia and enclosing medium to coarse grained syenite. Neys diatreme, south contact.

OLIVINE MONZOGABBRO CLASTS

The most abundant clasts are olivine monzogabbro and range in size from 2 cm to 20 m. The clasts are pitted from the weathering out of olivine and associated mafic minerals and display a faint alternating mesocratic to leucocratic compositional layering which is in part due to the relative abundance of olivine. The rock is reported to be composed of clinopyroxene, plagioclase (labradorite), perthite, nepheline (altered), olivine, and amphibole with minor biotite, chlorite, apatite and opaques (Balint 1977, p.43-50). This clast type appears to be equivalent to the alkaline gabbro described by Currie (1980) and Mitchell and Platt (1977) in the area of the former fishing village of Port Coldwell.

One thin section examined by the author from one of the large clasts within the breccia has a fine to medium grained, massive, equigranular, hypidiomorphic texture with local fine grained granoblastic patches. The granoblastic areas consist of rounded to subrounded pyroxene grains partially engulfed in plagioclase. The mode was visually estimated to consist of 40 percent clinopyroxene, 10 percent biotite, 5 percent magnetite, 40 percent plagioclase (An_{40-44}), and 5 percent olivine.

The clinopyroxene occurs as anhedral to subhedral rounded colourless grains, with narrow, turbid reaction rims on some grains. The reaction rim may consist of a very fine grained fibrous amphibole. Biotite and magnetite, as breakdown products of the pyroxene, locally occur along fractures within the mineral. Rarely some twinning is present. Clinopyroxene in places encloses rounded grains, likely of former olivine, that are completely altered to an unidentified reddish brown mineral.

Olivine occurs as anhedral grains between clinopyroxene grains. The olivine has broken down to magnetite and some biotite along the edges of internal fractures. Plagioclase forms anhedral, somewhat tabular grains, that are clear, faintly zoned, and in places have saussuritized margins. Plagioclase locally encloses small grains of clinopyroxene. Biotite is reddish brown, interstitial, very fine to fine grained, and may enclose magnetite. Magnetite

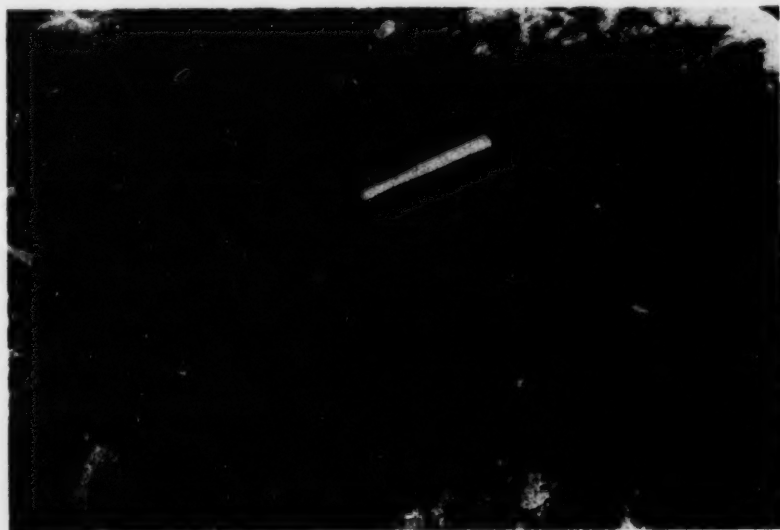


Photo 2. Wave polished surface of the breccia comprising the Neys diatreme.

DIATREMES NORTH OF LAKE SUPERIOR

is anhedral and is generally enclosed in biotite. Both magnetite and biotite are generally breakdown products of pyroxene and olivine. The magnetite-biotite is separated in places from pyroxene grains by narrow reaction rims which may be amphibole. Magnetite enclosed in pyroxene locally displays a narrow rim of amphibole shielding the grain and separating it from the unaltered pyroxene. The author did not observe the perthite, amphibole and nepheline reported by Balint (1977).

The clast is likely derived from the alkalic gabbro outer rim of the Port Coldwell sub-centre of the Port Coldwell alkalic rock complex.

ALKALI-FELDSPAR SYENITE CLASTS

Alkali-feldspar syenite clasts are locally derived from the enclosing host rock. Balint (1977, p.58) reported the clasts to be more saussuritized than the host. These clasts range from 10 to 100 cm in size (Balint 1977, p.28).

One thin section from a pyroxene syenite clast was examined by the author. The rock is medium to coarse grained, massive, equigranular, and hypidiomorphic. The mode is visually estimated to be 50 percent K-feldspar, 5 percent magnetite, 35 percent clinopyroxene, and 10 percent biotite. Clinopyroxene forms rounded to subangular grains interlocking with each other. Magnetite is locally intergranular to the pyroxene. The pyroxene is often turbid and altered to a very fine grained, fibrous amphibole with minor associated sericite. The biotite is brown and felty, and engulfs altered pyroxene aggregates. The biotite may also be in part after amphibole. K-feldspar is turbid, anhedral to subhedral, perthitic, somewhat elongated, and is interlocked with minor angular to subangular altered pyroxene. Magnetite is anhedral, and disseminated throughout the rock. Minor sericite is present as an alteration of the feldspar.

The syenite clast is derived from the nearby host rocks. Fractures in the clast are filled with matrix similar to that of the matrix of the breccia. Extensive alteration of the syenite and veining by gabbroic material makes mineral identification within the syenite clast difficult.

NEPHELINE SYENITE CLASTS

Nepheline syenite clasts contain orange spots of altered nepheline and range from 5 to 60 cm in size (Balint 1977, p.28, 60-62). This clast type is rare and was not examined in thin section by the author.

MAFIC HORNFELS CLASTS

Mafic hornfels clasts are the rarest of the four major clast types composing the breccia. These clasts range from 5 to 50 cm in size (Balint 1977, p.28) and consist of gneissic amphibolite containing greenish granular clots which weather out leaving a pitted surface. This rock type is composed of granoblastic plagioclase and orthopyroxene retrograded to amphibole (Balint 1977, p.72). Balint (1977, p.72) considered the mafic hornfels to represent pyroxene hornfels facies, retrogressed to hornblende hornfels facies. These inclusions are probably derived from the Early Precambrian greenschist to amphibolite facies (Walker 1967) terrain that envelopes the Port Coldwell complex.

The author had one thin section prepared from this minor clast type. The sample has a fine grained, inequigranular-seriate, poikiloblastic, granoblastic texture with straight grain boundaries. The mode was visually estimated to be 45 percent orthopyroxene-amphibole, 45 percent plagioclase (An_{44-52}), and 5 percent magnetite. The orthopyroxene forms colourless anhedral grains with moderate relief. The mineral locally occurs in almond-shaped aggregates of several grains of generally coarser texture than associated amphibole and plagioclase. Amphibole is present as large amoeboid grains with rounded inclusions of

plagioclase and orthopyroxene. The amphibole is poikiloblastic and dusted with tiny opaque inclusions. Plagioclase occurs as rounded to subrounded anhedral fresh grains.

Magnetite forms intergranular anhedral grains disseminated throughout, and also occurs as poikilitic inclusions in amphibole.

BRECCIA MATRIX

The breccia matrix consists of comminuted debris derived from the clasts it contains. This interclast material consists of olivine, hornblende, alkali feldspar, plagioclase, and opaques. Pyrite and pyrrhotite are locally abundant.

The author had two thin sections prepared from the matrix of the diatreme breccia. A brief examination of the sections disclosed a fine to medium grained, massive inequigranular-seriate, cataclastic-granoblastic texture. Grain boundaries are straight to lobate. The abundance of plagioclase, clinopyroxene, and olivine indicated the dominant source was comminuted olivine monzogabbro. Perthitic feldspars derived from the enclosing syenitic rocks are also present.

The margins of olivine grains have invariably been altered to dusty fine grained magnetite. Iddingsite, chlorite, and biotite are the other alteration products. The feldspars are turbid and the clinopyroxene relatively fresh. Fine-grained ragged chlorite and biotite are abundantly disseminated throughout the matrix. Feldspar-feldspar grain boundaries are interlocking and lobate. The matrix is altered and has undergone mild recrystallization.

The author considers the matrix to result largely from the comminution of alkalic gabbro. Balint (1977, p.78) favored such an interpretation but also suggested the possibility that it was generated by partially crystallized gabbroic magma accompanying the invading gas of the diatreme.

Trachytic Nepheline Syenite Dike

Along the south contact of the diatreme and the enclosing syenitic rocks, a sinuous, pink, nepheline syenite dike has been emplaced which varies from 0 to 30 cm in width. Tabular feldspars are oriented parallel to the strike of the contact and define a trachytoid texture. Balint (1977, p.80) reported that the dike consists of alkali feldspars, nepheline, dark green-brown amphibole, and minor sphene. The rock unit is minor and was not examined in thin section by the author.

Quartz-Bearing Microsyenite Dike

In the northern portion of the diatreme, a fine-grained, bright red to red-brown aphanitic dike cuts the breccia but not the enclosing wall rocks. Grain size is coarser towards the centre of the dike, which encloses xenolithic fragments of the diatreme breccia (Photo 3). Balint (1977, p.85-86) reported that the dike is composed of alkali feldspar, plagioclase, anhedral blue-green amphibole altered to biotite, and minor quartz.

The author had one thin section prepared from this dike. The rock is fine grained, massive, allotriomorphic with lobate to curved grain boundaries. The mode is visually estimated to be 5 percent quartz, 10 percent amphibole, 10 percent microcline, and 75 percent perthite. Trace amounts of carbonate, plagioclase, and apatite were noted.

Quartz occurs as clear, interstitial, anhedral grains. Amphibole is present as pale green, pleochroic, interstitial grains stained with iron oxide. Amphibole is also common as rounded elongated grains poikilitic in perthitic feldspar. Microcline forms anhedral grains interlocking with perthite. The feldspar is turbid and contains rare faint vestiges of albite twinning. Perthite is the dominant feldspar. It is anhedral and interlocking, and in places the outer margin may be rimmed with colourless albite. The plagioclase content is greater than

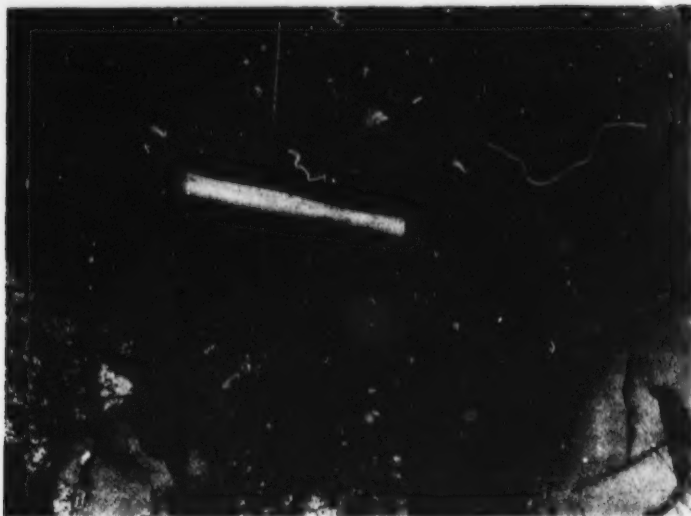


Photo 3. *Fragments of breccia within a equigranular fine grained quartz syenite dike. Neys diatreme.*

the K-feldspar and thus it could be classified as an antiperthite. The perthite is a string perthite, turbid, and shows some Carlsbad twinning. The narrow, clear albite plagioclase rims commonly occur in the gaps between interlocking perthite grains.

This dike is likely related to an intrusive phase of the Pic Island subcomplex and its emplacement was controlled by the diatreme structure.

ORIGIN OF THE NEYS DIATREME

Balint (1977, p.88, 91) concluded that the rounded nature of the clasts implies clast transport in a highly turbulent flow as the result of high velocities achieved by a gas-solid phase of a volatile-rich magma. The author concurs with Balint in this interpretation. Balint (1977,

TABLE 2. MAJOR FEATURES OF THE NEYS DIATREME (BALINT 1977, P. 91, 92).

1. The diatreme is associated with mafic alkaline igneous activity.
2. Physically the diatreme consists of a framework of clasts of varying shape set in a finer comminuted matrix.
3. The diatreme intrudes contemporaneous intrusive rocks but not late stage dikes.
4. The diatreme has a shape between dike-like and pipe-like.
5. The emplacement of the structure is fracture controlled.
6. There is evidence of concentration of larger clasts towards the outer edges of the structure.
7. No significant thermal metamorphic effects, as a result of the diatreme, were observed.
8. Tectonic block faulting possibly initiated the diatreme formation. Evidence for this type of faulting is found in the Port Coldwell complex.

TABLE 3. MAJOR ELEMENT ANALYSES OF VARIOUS PHASES OF NEYS DIATREME (COMPILED FROM BALINT 1977).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO ₂	48.70	53.42	53.40	44.79	47.40	50.92	51.41	53.63	53.79	43.46	46.12	47.52	63.69	62.87	55.42
Al ₂ O ₃	21.16	21.12	21.61	8.87	14.00	15.97	19.86	19.33	21.71	6.74	13.10	12.09	17.24	16.86	15.97
Fe ₂ O ₃	3.16	2.06	2.45	3.70	4.14	2.11	2.54	3.64	2.62	7.31	3.02	2.03	2.62	2.81	1.84
FeO	5.88	3.42	3.74	12.48	7.40	5.38	3.85	4.82	3.46	10.10	7.00	8.04	2.07	2.47	6.06
MgO	4.07	2.24	2.24	16.84	8.99	8.44	2.30	2.55	1.79	15.61	8.86	10.36	1.18	1.33	3.01
CaO	7.52	3.73	4.07	8.78	9.68	8.93	4.78	4.16	3.87	11.11	12.23	9.82	0.68	0.13	5.37
Na ₂ O	2.61	6.14	4.07	1.58	3.24	3.84	6.59	5.33	4.38	1.41	2.84	3.14	5.63	6.48	4.93
K ₂ O	4.30	5.01	4.98	0.89	2.26	2.37	5.62	3.66	4.89	0.26	2.59	3.26	5.58	5.68	4.44
TiO ₂	0.81	0.62	0.58	0.59	0.75	0.37	0.80	0.94	0.52	2.51	2.00	0.70	0.59	0.65	0.83
P ₂ O ₅	0.58	0.31	0.28	0.45	0.63	0.63	0.42	0.40	0.20	0.61	0.53	0.46	0.03	0.08	0.41
MnO	0.18	0.10	0.17	0.42	0.23	0.17	0.13	0.15	0.10	0.24	0.26	0.30	0.18	0.13	0.25
CO ₂	1.43	0.59	0.48	0.18	0.26	0.29	1.14	0.55	0.33	0.26	0.59	0.40	0.00	0.26	0.62
H ₂ O	1.17	0.99	2.43	0.45	1.17	0.72	0.90	0.99	2.61	0.36	1.89	1.44	0.27	0.54	1.26
TOTAL	99.88	98.77	98.28	100.03	100.18	100.14	100.32	100.21	100.27	99.98	100.03	100.16	99.77	100.28	100.40

SAMPLES

1. Dark central phase of composite dike. Sample C545
2. Leucocratic phase intruding central phase. Sample C544.
3. Leucocratic subparallel dike. Sample C501.
- 4-8. Olivine monzogabbro clasts. Samples C522, 525, 537, 514, 536.
9. Nepheline syenite clast. Sample C531.
10. Malic hornfels clast. Sample C518.
- 11-12. Matrix of breccia.
13. Central portion of quartz-bearing microsyenite dike. Sample C529.
14. Chilled margin of quartz-bearing microsyenite dike. Sample C502.
15. Hybrid portion of dike interfingering with intrusive breccia. Sample C519.

DIATREMES NORTH OF LAKE SUPERIOR

p.91, 92), considered the Neys diatreme to fit other models proposed for diatremes. Table 2 summarizes the important features of the diatreme, pertinent to its genesis (Balint 1977, p.91, 92). Table 3 gives the chemical composition of the various phases of the Neys diatreme (Balint 1977). Note that the locations of the samples are only approximately known.

The author did not observe evidence for a fracture that controlled emplacement of the diatreme. Hard evidence for block faulting has not been observed by the author or cited by Balint (1977).

The author considers the Neys diatreme to be comparable with breccia formation at relatively high stratigraphic levels in a porphyry copper type environment. This model has been described by Norton and Cathles (1973), Gilmour (1977) and Sillitoe and Sawkins (1971).

Structural Geology

Banding and trachytoidal texture attitudes within the enclosing coarse grained syenite have a north trend and are steeply dipping to the east or nearly vertical and parallel to each other. The composite dikes have an irregular northwest trend and widths may exceed 1 m. The breccia mass cutting the coarse grained syenite has a north of east trend and appears to pinch out to the east. The intrusive breccia may or may not widen westward beneath Lake Superior. Balint (1977) related the diatreme to block faulting within the Port Coldwell complex; however he did not cite evidence to support this interpretation. The present level of exposure of the Port Coldwell complex is relatively high, as indicated by miarolitic cavities, abundant xenolithic inclusions and a sharp cross cutting contact relationship with the enveloping Early Precambrian rocks. The author has also observed hornfelsed Early Precambrian rocks overlying rocks of the complex. The author considers the Neys diatreme to be a reflection of this relatively high level of exposure of the Port Coldwell complex. The diatreme structure likely resulted from the accumulation of volatiles within the alkalic magma in a manner perhaps similar to that proposed by Norton and Cathles (1973). They proposed that volatiles collect (in an apical region) beneath a cooled rind of an intruding magma and later pierce this rind forming an intrusive breccia. Consequently the author does not consider the Neys diatreme to be similar in origin to others discussed in this report and would interpret it as a shallow feature with no great depth extension.

Economic Geology

In 1976 the author examined and collected a large sulphide-bearing sample (30 by 15 by 15 cm) from this breccia. Pyrite and pyrrhotite were disseminated throughout the sample and visually estimated to be approximately 5 percent. The assayed sample consisted of both matrix and clasts. A 32 element spectrographic analysis of the sample failed to detect anything of economic interest (Geoscience Laboratories, Ontario Geological Survey, Toronto). During the past field season, the author tested the structure with a spectrometer and no radioactivity was detected. The diatreme appears to have little direct economic interest. No record exists of any work being done on this structure in search of economic mineral deposits.

SLATE ISLANDS DIATREMES

LOCATION AND ACCESS

The Slate Islands (2 on Figure 1) lie approximately 11 km off the north shore of Lake Superior directly south of the town of Terrace Bay. The islands are approximately 32 km southwest of the Port Coldwell alkalic complex. The islands are located at 48°39'30''N Latitude and 87°W Longitude. Easiest access to the islands is by boat from Terrace Bay.

General Geology

The general geology of the islands is described by Sage (in preparation). The islands are dominantly composed of Early Precambrian metavolcanics intruded by massive gabbro to diorite bodies, feldspar porphyry, and quartz-feldspar porphyry. On the west shore of Patterson Island a thin (approximately 21 m in width) hematite, chert, and argillite unit of Middle Precambrian Gunflint Iron Formation unconformably overlies the Early Precambrian. This exposure appears to be the presently known eastern limit of the Gunflint Formation. The unit has been extensively broken up by diatreme activity. Overlying the Gunflint in angular unconformity are Late Precambrian amygdaloidal mafic volcanic flows with interbedded red siltstone and sandstone. These Late Precambrian rocks have been correlated with the Osler Formation (Halls 1974). The Late Precambrian rocks have been broken up at the base of the section by diatreme activity. The sequence is approximately 120 m thick. The islands and the base of the Late Precambrian section have been intruded by an extensive swarm of diabase dikes. Cutting the southwest corner of Patterson Island is a lamprophyre dike with carbonatitic affinities containing olivine phenocrysts up to 1 cm in maximum dimension. The dike has been dated by K-Ar techniques at 282 ± 11 Ma and 310 ± 18 Ma by D. Watkinson (Carleton University, personal communication, 1977). The dike therefore represents the youngest dated alkalic intrusive event in this region and within the alkalic petrogenetic province north of Lake Superior. The Slate Islands diatremes represent a still younger undated event. Cutting all rock types, including the lamprophyre dike, are intrusive breccias. The breccias are most common on Patterson Island but examples are found on most of the islands within the group. Along the west coast of Patterson Island the breccias locally occur preferentially along the Late Precambrian - Early Precambrian contact and form a completely ramifying pattern which in places encloses large blocks of Early Precambrian rocks in relatively unrotated position. The ramifying pattern of breccia development in a highly fissile rock implies explosive rather than passive emplacement. Shock metamorphic features accompany the diatremes in the form of shatter cones in exposed outcrop and microscopically as deformation lamellae on quartz grains within the breccia matrix (Sage 1978). The author considers diatreme emplacement and shock metamorphism to be part of the same event, which is related to the petrologic and evolutionary history of the alkalic rock province north of Lake Superior and not the product of meteoric impact as suggested by Halls and Grievess (1976). The breccias consist of metavolcanic and diabase fragments up to 4 by 4 m in size in a comminuted matrix derived from the clasts. With two exceptions the breccia clasts are unsorted and lack visual evidence of hydrothermal alteration. Thin sections of an unaltered alkalic diabase dike at the contact with a breccia dike indicate microscopically the development of contact metamorphism of albite-epidote hornfels facies, marginal to the breccia dike, and which is largely the result of hydration. The red colour of the diatreme along the west shore of Patterson Island is believed to be largely due to comminuted Gunflint ironstone in the breccia; however a slight reddening of the breccias on the east shore indicates a minor introduction of hematite into the breccia. The breccias break easily when hammered, and have not been as extensively altered by hydrothermal events as those on the mainland opposite the islands. One dike on Spar Island displays a pronounced zoning of clast sizes with the larger clasts concentrated

DIATREMES NORTH OF LAKE SUPERIOR

in the centre; and one large breccia dike on the east shore of Patterson Island displayed zoning of clastic debris over widths of several centimetres marginal to larger fragments. This observation implies local laminar flow perhaps during the waning phase of gas discharge. An intrusive breccia lying on top of a diabase sill, and cutting through Late Precambrian extrusive rocks on the west shore of Patterson Island has a diabase matrix, and is the only breccia found on the islands with an igneous matrix. Rounded chert fragments (Gunflint) coated with chilled diabase and fragments of the diabase occur within the breccia. The author considers this to be the leading edge of igneous dike rock accompanying diatreme formation, and would correlate this intrusive breccia with the Late Precambrian diatreme event, better developed on the mainland, rather than a Middle Paleozoic event as is geologically indicated for all other intrusive breccias found on the Slate Islands.

The largest diatreme exposed on the west coast of Patterson Island displays good evidence of hydrothermal alteration, in the form of well developed bleaching of clast rims.

To avoid duplication, information given in Sage (1978) is not repeated here and the reader should refer to that article for additional detail.

Structural Geology

The structural geology of the islands is as complex as the lithology. The islands represent a southwest plunging (approximately 60 degrees) fold nose, on which minor folds have been superimposed by shearing between Mortimer and Patterson Islands (Sage in preparation). The circular pattern of the islands is thus a function of bed rock geology, and not meteoric impact, as suggested by Halls and Grieves (1976). The islands occur along a submerged southwest-striking ridge projecting southwestward from the west flank of the Port Coldwell complex through Ashburton Bay (Sage in preparation). Extensive Early Precambrian (gabbro and diorite) and Late Precambrian (diabase) mafic intrusions have helped shield the fissile Early Precambrian rocks from glacial erosion, and thus preserved the circular patterns (Sage in preparation). Such pervasive Early and Late Precambrian mafic intrusions have not been observed on the mainland by the author. The penetrative schistosity found in the Early Precambrian is not present within the Middle Precambrian, implying that deformation of the Early Precambrian was pre-Gunflint. Undoubtedly, the Early Precambrian structures were reactivated during later events.

Additional detail on the regional setting of the islands is given in the discussion of structural geology of the Dead Horse Creek diatreme (below).

Economic Geology

During mapping in 1974 the author routinely checked rock samples with a geiger counter without detecting radioactivity. Because of recent developments on the mainland the author decided to recheck the major intrusive breccias with a spectrometer. Most of the larger structures were checked, but no radiation was detected. While texturally and structurally similar to the mainland breccias, the Slate Islands breccias lack the extensive hematization and silicification found within the mainland breccias which are radioactive. The lack of extensive hydrothermal activity within the Slate Islands breccias has undoubtedly helped to preserve the shock features found within the matrix, and in part, explains their lack of mineralization. Sulphide mineralization was not observed within the Slate Island structures, whereas sulphides are common in the radioactive mainland breccias. Other than dusty hematite, carbonate appears to be the only mineral that is recognizable as having been introduced.

Figure 5 gives the location of samples taken for chemical analysis and spectrometer readings. Table 4 (Chart B, back pocket) is a summary of minor element analyses completed on a number of breccia samples and respective wall rocks. Figure 6 shows

graphically the chemical differences between breccia and wall rock. Table 5 gives spectrometer readings for the same sites.

The spectrometer readings (Table 5) display no consistent pattern, and disclose no obvious difference in relative radioactivity between breccia and wall rock. Apparently the potassic metasomatism and uranium-thorium mineralization typical of the McKellar Creek and Dead Horse Creek structures were absent here.

The analysis of fine grained breccia matrix and wall rock for phosphorous, strontium, titanium and barium was undertaken in an attempt to establish alkalic magmatic affinity for the breccias. The results are, in general, inconclusive. There is little variation in relative quantities of the minor elements; however location S-6, which is the largest diatreme exposed on the islands and the only breccia displaying visual evidence of alteration, displays some differences. On the basis of three paired breccia - wall rock samples, barium and strontium are depleted to one-quarter in the breccia relative to the wall rocks, phosphorous is depleted to half, and titanium appears largely unaffected (see Table 4, Figure 6). Sodium has been depleted in the breccia to about one-fifth the quantity found in the wall rocks. While this data in itself does not prove alkalic affinity, taken in context with other evidence for alkalic magmatism within the region, it suggests that an alkalic model is acceptable for the origin of the diatreme structures. The depletion of these elements is undoubtedly a function of fluids causing the alteration. This fluid displays a tendency to scavenge those elements found concentrated in the alkalic environment. The nature of the fluids causing

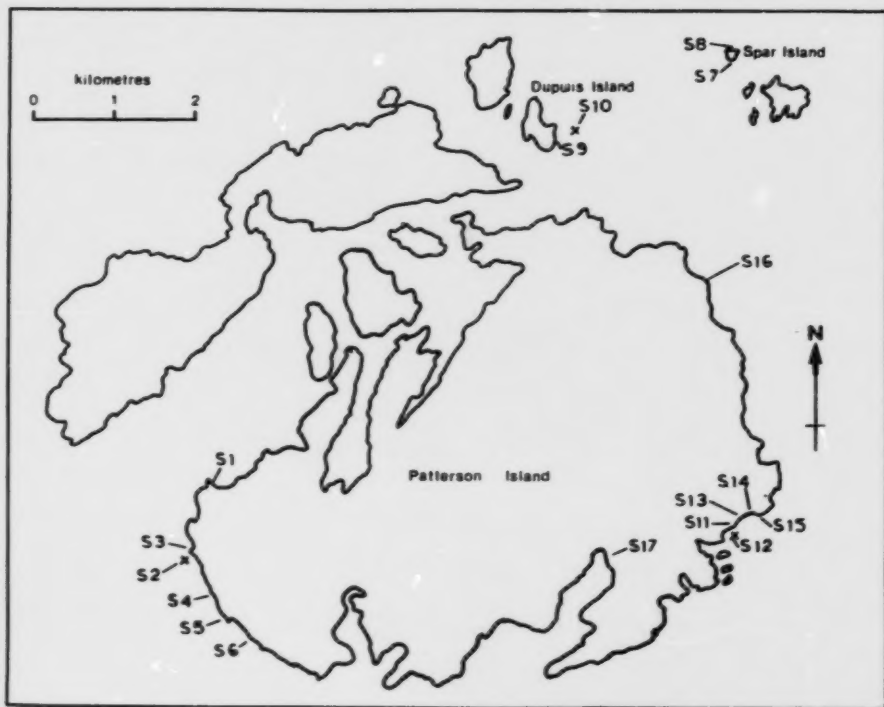


Figure 5. Locations of samples taken from the Slate Islands diatremes.

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the alteration, and the origin of these fluids is unknown. The fluids undoubtedly did not contain the high concentrations of uranium, thorium, beryllium, rare earths, and phosphorous that altered the McKellar Creek and Dead Horse Creek structures. Perhaps the fluids were derived from a less alkaline source than the ones active at the above two structures. The chemistry of the McKellar Creek and Dead Horse Creek structures suggest a carbonatitic magma as a source. Perhaps the Slate Island breccias are the result of fluids from a magma of more gabbroic composition.

The contrasting degree of alteration between the Slate Island diatremes, and the McKellar Creek and Dead Horse Creek structures, suggests that the fluids active on the Slate Islands were also less reactive with the wall rocks, and were perhaps more transient in nature.

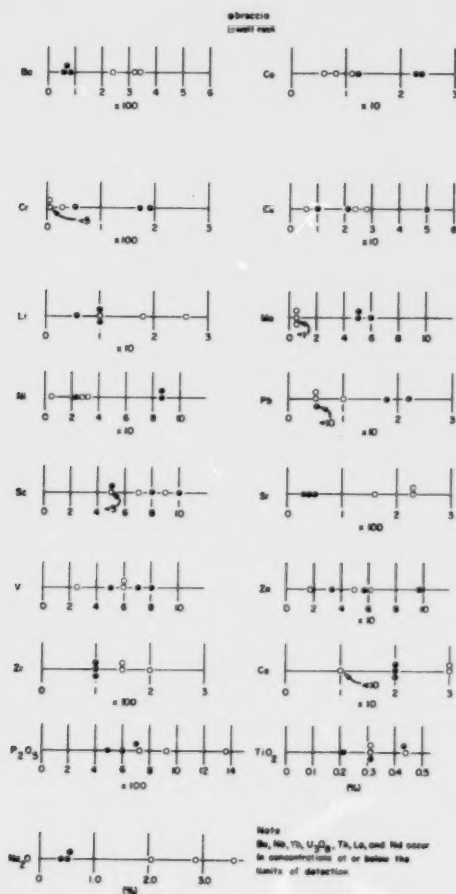


Figure 6. Distribution of minor element abundances in wall rock and breccia at Slate Islands diatremes.

TABLE 5. SPECTROMETER READINGS FOR SLATE ISLAND DIATREMES AND ENCLOSING ROCKS.

Location			Breccia			Wall Rock		
Location			Breccia			Wall Rock		
S1	T1	1500	S17 (ave. of 3)	T1	3000	T1 T2 T3	2000 150 47	2000 163 43
	T2	90		T2	163			
	T3	50		T3	43			
S2	T1	1800	S11	T1	2450	T1 T2 T3	900 100 50	2000 110 27
	T2	130		T2	160			
	T3	40		T3	51			
S3 (ave. of 2)	T1	1750	S12	T1	2900	T1 T2 T3	2450 160 51	2900 250 27
	T2	130		T2	250			
	T3	28		T3	27			
S4	T1	2000	S13 (ave. of 2)	T1	1800	T1 T2 T3	1500 100 53	1800 210 14
	T2	170		T2	210			
	T3	45		T3	14			
S5	T1	1000	S14	T1	1900	T1 T2 T3	1600 1700 130	1900 150 32
	T2	50		T2	150			
	T3	40		T3	32			
S6 (ave. of 3)	T1	1733	S15	T1	2150	T1 T2 T3	1666 229 31	2150 155 52
	T2	59		T2	155			
	T3	33		T3	52			
S7	T1	1400	S16	T1	1300	T1 T2 T3	1600 120 25	1300 1000 80
	T2	120		T2	90			
	T3	28		T3	44			
S8	T1	1500	S9	T1	1000	T1 T2 T3	1500 100 50	1000 80 28
	T2	110		T2	80			
	T3	50		T3	28			

NOTES.

1. Entries left blank are sites lacking in respective breccia/wall rock outcrop.

2. All readings in counts per minute.

3. T1 = Th+U+K. T2 = Th+U. T3 = Th.

DIATREMES NORTH OF LAKE SUPERIOR

MINERAL EXPLORATION

The islands were extensively explored for gold around 1898; considerable trenching was completed and two adits driven on the northwest corner of Patterson Island (Parsons 1918). Sometime after this early work, unknown individuals drove an adit on a sulphide showing at Lambton Cove on Mortimer Island. Between 1960 and 1963 Kimberly Clark Canada Limited stripped and diamond drilled (6,581 feet) the area north of Horace Cove on Patterson Island for gold. These showings were previously known and reported by Parsons (1918). The company also located a previously unknown gold showing designated as the 'Cosen's showing' in the interior of Patterson Island. The gold occurs in milky quartz veins and along the foliation planes of schist marginal to the veins. Assays in excess of several ounces per ton (private files donated to the Ontario Ministry of Natural Resources by Kimberly Clark Canada Limited) were not rare, but short lengths and narrow widths discouraged additional work at that time. Patterson Island represents a fold nose in the Early Precambrian stratigraphy and the gold mineralization appears to occur preferentially along the fold axis. The gold mineralization is typical of Early Precambrian gold mineralization found in 'greenstone' terrains and appears unrelated to the diatremes.

Although the Slate Islands have other rock suites of potentially high economic value, the breccias appear to be of only academic interest.

MCKELLAR CREEK DIATREME

LOCATION AND ACCESS

The McKellar Creek diatreme (4 on Figure 1) is located at approximately 48°49'03''N Latitude and 86°42'40''W Longitude. The intrusion can be reached easily by a trail leading north from Highway 17 just west of the bridge over McKellar Creek. The structure is located approximately 300 m north of Highway 17. The complex is exposed in two outcrops located in its southwest corner, and numerous patches of radioactive rubble derived from weathering of the complex, which have been exposed by recent logging operations.

General Geology

On the basis of limited exposure the diatreme (Figure 7, Chart A, back pocket) has a north-south long axis of approximately 240 m and a maximum width of approximately 60 m. The site of the breccia is surrounded by extensive outcrops of Early Precambrian, fine-grained, schistose argillite and siltstone. These metasediments are rather homogeneous, rarely show good bedding, and commonly contain an estimated 20 percent or more biotite. The metasediments have been intruded by north-trending diabase dikes which were not observed to cut the breccia. Several lamprophyre dikes were observed but the relationship of these dikes to the breccia is also unknown.

EARLY PRECAMBRIAN

Metasediments

The metasediments enclosing the diatreme weather grey to grey brown, and on the fresh surface are grey to greenish grey. Locally crude compositional layering reflects former bedding, and on the weathered surface tiny bluish quartz grains are visible with the aid of a hand lens.

In one thin section the rock is fine grained, inequigranular, and granoblastic with curved to straight grain boundaries. The mode is estimated to be 30 percent quartz, 35 percent biotite, and 35 percent plagioclase. The biotite occurs in tabular, ragged grains with a subparallel orientation which defines a schistosity. The quartz is anhedral, angular to subrounded in outline and locally occurs in aggregates of several grains. The plagioclase occurs as anhedral turbid grains interlocking with the quartz. The plagioclase is rarely twinned. Petrographically the rock is a quartz-biotite-plagioclase schist.

LATE PRECAMBRIAN

Diatreme Breccia

The diatreme breccia consists of rounded to angular clasts (Photos 4 and 5) of pink and white quartzite, metasediments, and, rarely, altered trondhjemite. The clasts generally do not exceed 0.3 m in maximum dimension, but one clast of quartzite in a small outcrop immediately east of the two main outcrops is 2 by 3 m in size.

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Photo 4. Breccia, McKellar Creek diatreme. Light colored clasts are quartzite from the Sibley Group. Location P-1.

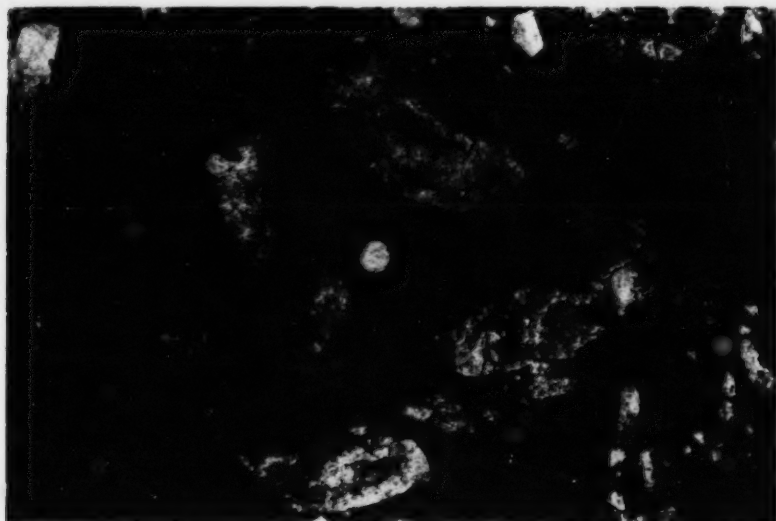


Photo 5. Close up of angular fragments comprising the McKellar Creek diatreme breccia. Light colored fragments are from the Late Precambrian Sibley Group. Most of the remaining clasts are derived from the enclosing Early Precambrian metasediments.

The quartzite clasts were considered by Mitchell and Platt (1977) to be from the Sibley Group, and the author agrees with this interpretation. The clasts of quartzite are more rounded than the clasts of Early Precambrian metasediments, and on weathered surface chalky white specks derived from the weathering of feldspar are visible, indicating the rock is an arkosic quartzite to arkose. The rounding of the clasts is likely due to milling of the fragments during emplacement of the breccia. The presence of these clasts within the breccia suggests that the Late Precambrian Sibley Group once covered this area, but has been subsequently removed by erosion. The presence of these clasts at a stratigraphically low level has been described and explained experimentally by McCallum *et al.* (1976) and Woolsey *et al.* (1975). The clasts represent sloughing of the overlying rocks accompanying collapse of the gas column during the waning phase of emplacement. The slate clasts are of local origin, derived from the enclosing metasediments. The clasts are reddened (hematized) and silicified. The larger clasts are locally more altered along the rims than within the cores. This reddening and hardening (silicification) of the metasediments rapidly disappears away from the breccia-wallrock contact indicating the hydrothermal effects were largely restricted to the breccia. The width of visible alteration of the enveloping rocks is estimated to be a maximum of 3 to 6 m.

The breccia is harder to break than the Slate Islands breccias, but not as hard as the Dead Horse Creek breccias. The Slate Islands breccias break around the clasts; while the McKellar Creek breccias break around and through the clasts. The Dead Horse breccias commonly break through the clasts. This feature is undoubtedly related to the degree of hydrothermal alteration.

METASEDIMENTARY CLASTS

Angular clasts of metasediment locally derived from the Early Precambrian wall rocks are the dominant clast type within the breccia. These clasts were referred to as slate by Walker (1967). In outcrop the red and altered clasts in association with the quartzite clasts form a breccia with a clast-supported framework. The matrix of comminuted and altered rock fills the gaps between the fragments, and locally weather preferentially with respect to the fragments due to the high carbonate content within the matrix. The largest metasedimentary clast was 15 by 12.5 cm in maximum dimension.

In thin section the clasts of metasediment are seen to consist of approximately 15 percent angular grains of quartz, 15 percent saussuritized plagioclase (An_{35-50}), and a very fine grained granoblastic matrix of plagioclase and possible quartz. The quartz grains display a well developed undulatory extinction. The long axes of these clastic grains are sub-parallel and define a foliation within the rock. Rare euhedral crystals of pyrite are present. The clast is impregnated with carbonate, and the reddish brown to brown stain associated with the carbonate is likely an iron oxide. J. Franklin (Geologist, Geological Survey of Canada, personal communication, 1979) has suggested, on the basis of a thin section he examined, that some of the fragments may be of the Middle Precambrian Rove Formation.

TRONDHJEMITE CLASTS

One very rare clast type was originally thought to be a quartz syenite related to the Port Coldwell complex. The rock is fine to medium grained, equigranular and bright red in colour. In thin section the rock was seen to be a trondhjemite, and not like samples from the Port Coldwell complex examined in thin section by the author. The rock may be an altered Early Precambrian dike rock common to the region; however, the author did not observe similar dikes in proximity to the diatreme. The age and/or origin of the granitic clast remains problematical, but the author prefers to interpret it as being of local origin, derived from trondhjemite dike(s) cutting the enclosing metasediments at depth.

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The trondhjemite consists of bright red feldspar and quartz. The largest clast found was 4 by 4 cm in maximum dimension. The grains are fine to medium, equigranular, and allotriomorphic, with curved to straight boundaries. The original texture may have been fine grained, massive, equigranular, hypidiomorphic, but metamorphism has somewhat obscured it. The mode was visually estimated to be 10 percent quartz, 65 percent plagioclase (An_{36} ?), 20 percent carbonate and brown stain, and possibly 5 percent K-feldspar. The quartz is anhedral, interstitial, with curved to lobate grain boundaries. Undulatory extinction, occasionally in bands across the grains, is well developed, and trains of bubbles with possible crystallographically controlled location are present in some grains. One inclusion train defines a curved surface, while others are crudely subparallel. Plagioclase occurs as anhedral to subhedral, turbid grains. The grains are often considerably fractured; carbonate and brown iron oxide alteration fill the fractures and irregularly replace the feldspar. Several feldspar grains are untwinned and appear to be more altered than those clearly identified as plagioclase. These grains may be former K-feldspar.

Carbonate, in close association with brown stain, possibly an iron oxide, not only fills fractures in the feldspars and replaces feldspar, but also occurs interstitially to the other minerals throughout the rock. The red colour of the clast undoubtedly is due to this iron-rich carbonate and dusty disseminated fine grained iron oxide.

QUARTZITE CLASTS

The most abundant clast type is arkosic quartzite to arkose. The clasts are fine grained, pink to white, and upon close inspection commonly display chalky white specks from weathering of feldspar grains. In one poorly exposed rubbly outcrop (15 by 22 m) west of the two main outcrops, one block of rounded quartzite 2 by 3 m in size was observed. Most clasts are much smaller and the largest clast found within the two main exposures was 45 by 32 cm.

The clasts are rounded to subrounded, most likely due to milling during fluid discharge at the time of emplacement. The quartzite clasts are considered by Walker (1967), Mitchell and Platt (1977) and the author to be from the Late Precambrian Sibley Group.

In thin section the quartzite texture is fine grained, equigranular, allotriomorphic, clastic, and granoblastic with curved to straight grain boundaries. The mode is visually estimated to be 70-75 percent quartz, 15 percent plagioclase (An_{30-40}), 5-10 percent microcline, and 5 to 10 percent matrix. The specimens contain several rounded grains of chert which may reach one volume percent of the rock. The clastic chert grains are rounded to subangular in outline.

The quartz grains display undulatory extinction, occasionally extinction in bands, and trains of bubble-like inclusions. The bubble-trains do not appear to be as well developed in the quartzite clasts as in individual quartz grains found in the breccia matrix. The bubble trains are identical to those found in quartz grains of the trondhjemite clasts.

Microcline is rounded to subangular in outline and relatively fresh in appearance. The microcline displays good quadrille twinning. Plagioclase is more angular in form than the quartz. The plagioclase grains are flecked with saussurite but not extensively altered. The rare chert fragments consist of an interlocking aggregate of anhedral grains which are rounded in outline. The matrix of the quartzite consists of very fine grained carbonate and quartz which cements and holds the grains together.

The quartzite appears to be the product of weathering and reworking of detritus from a granodiorite to trondhjemite province. The chert may have been derived from the stratigraphically lower, Middle Precambrian Gunflint Formation.

BRECCIA MATRIX

The breccia matrix is variable between sections. The variation in texture and mineralogy between samples appears to be the result of the variation in intensity of the alteration.

Angular fragments of quartz and plagioclase feldspar are abundant in the breccia matrix. The feldspars are turbid (An_{28} ?) and in part saussuritized. Several grains of possible microcline were observed. The quartz and plagioclase chips within the matrix are the result of milling of Sibley Group quartzite clasts. All gradations between individual quartz grains and distinct fragments of Sibley Group rocks were observed.

The quartz grains display weak wavy extinction, occasionally in bands, and are rarely well rounded in shape. The quartz chips locally contain bubble trains.

Carbonate is abundant in the matrix, and it envelopes some clastic grains. Carbonate also impregnates some clasts, and may presumably be stained brown from iron oxide. The lack of carbonate within the enclosing wall rocks indicates that the carbonate found in the breccia has been introduced.

The McKellar Creek breccia matrix does not have the extensive development of amphibole or impregnation of disseminated sulphides that the Dead Horse Creek structure has. The McKellar structure is much more altered than the Slate Island diatremes, but in turn is less altered than the Dead Horse structure. The appearance and type of alteration present, i.e. hematite, silicification, and carbonate, suggests that the McKellar Creek and Dead Horse Creek diatremes are likely related to the same explosive event.

DEFORMATION LAMELLAE IN QUARTZ

Quartz grains in trondhjemite clasts, quartzite clasts, and the breccia matrix contain bubble trains reminiscent of deformation lamellae in quartz chips from the diatreme breccias of the Slate Islands. While likely of the same origin as the ones found on the islands, more in-

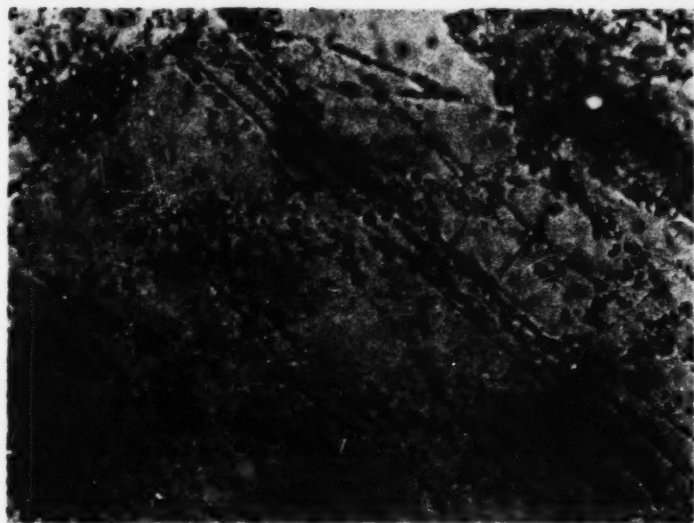


Photo 6. Planar features in a quartz grain from Sibley Group clast. Diameter of grain (approximately height of photo) is 0.4 mm. Note tiny bubbles along planar structures. The reader should compare this photograph with those of Gold (1968) to observe apparent similarity with samples from Brent structure.

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tense hydrothermal activity associated with the McKellar Creek structure may have modified them through recrystallization or annealing.

These strings of bubble-like inclusions occur in crudely subparallel groups, and along curved surfaces. Those that are subparallel may reflect crystallographic control. Whether they are true deformation lamellae related to the explosive emplacement of the diatreme is unclear. J. Franklin (1979, personal communication) informed the author that the possible lamellae are not typical of quartz found in the Sibley Group; their formation in the Sibley and trondhjemite clasts is therefore probably related to diatreme emplacement. The author believes that the Slate Island and McKellar structures formed in a similar manner from fluids originating from differing sources.

Thin sections showing the best developed planar structures in quartz (Photo 6) were examined by Darko Sturman, mineralogist, Royal Ontario Museum, using universal stage techniques. These planes are not as well developed as those previously reported from the Slate Islands (Sage 1978). The planes in the McKellar grains are slightly irregular, and on the basis of lack of sharpness of some planes when oriented on the universal stage, some of them may be slightly curved. The spacing of the planes is wider and much more irregular than those observed in samples from the Slate Islands. Hydrothermal alteration of the McKellar Creek breccia may have sealed the planar features and/or promoted annealing or recrystallization along the planes, producing an appearance of poorer planar development when compared with the Slate Island breccias. The orientation of the planes to the *c* crystallographic axis of quartz, given in Table 6 for the McKellar Creek samples, are generally the same as those given by Halls and Grieves (1976), rather than those cited by the author (Sage 1978) for the Slate Islands. The major difference between the McKellar Creek and the Slate Islands plane orientations is the dominance of the (1013) plane (20 degrees to the *c*-axis), and perhaps the presence of the (0001) plane (0 degrees to the *c*-axis) in the Slate Island breccias. The McKellar Creek quartz grains display a dominance of (1011) (50 degrees to the *c*-axis) and (2241) (80 degrees to the *c*-axis) plane orientations. The microscopic structures appear similar to those illustrated and described by Gold (1968) from the Brent structure which has been ascribed to meteorite impact by Robertson and Grieve

TABLE 6. CRYSTALLOGRAPHIC ANGLES MEASURED BETWEEN C-AXIS OF QUARTZ AND THE NORMAL TO PLANAR STRUCTURES IN THE QUARTZ GRAINS. MCKELLAR CREEK DIATREME.

Grain	0°	20°	50°	80°
1	2	—	—	—
2	—	20	—	—
3	—	—	50	—
4	—	20	51	85
5	—	—	50	—
6	—	—	—	88
7	—	—	55	—
8	—	—	—	78
9	—	—	—	77
10	—	—	60	—
11	—	—	—	79
12	—	—	20	—
13	—	—	42	—

Universal stage measurements by Darko Sturman, Mineralogist, Royal Ontario Museum.

(1975), but interpreted by Currie (1971) and Lumbers (1973) as a site of alkalic magmatism. As stated above, the author interprets the structures north of Lake Superior as diatreme emplacements (Sage 1978). The Slate Islands and mainland diatremes are similar in appearance with the exception of (1) a much higher degree of alteration associated with uranium-thorium mineralization in the mainland structures, and (2) an older age of the McKellar Creek and Dead Horse Creek diatremes. The Slate Islands and mainland diatremes occur along the same regional structure that controlled the location of alkalic rock-carbonatite magmatism north of Lake Superior. The occurrence of two meteor impacts on the same regional structure at approximately the same site (32 km apart) separated in time by 700 Ma would be extremely fortuitous. The differing ages of the Slate Islands and McKellar Creek-Dead Horse Creek diatremes, and differing degrees of hydrothermal alteration, are not considered by the author as indicative of contrasting different modes of formation but contrasting magmatic sources for the fluids. A tectonic-diatreme origin, in the opinion of the author, is most consistent with the geological data.

Structural Geology

The diatreme occupies a topographic low and occurs within a north-trending linear. The breccia may have been emplaced within a shear or fault zone, however, geologic data supporting this possibility are lacking. The rather homogeneous lithologies east and west of the structure have prevented the identification of any offset across the topographically low ground. There is no apparent zonation of clast size, but this may be a function of lack of exposure. The reader should refer to the Dead Horse Creek section for additional detail on regional structural geology.

Economic Geology

The breccia was found by Walker (1967) who interpreted it as Animikie conglomerate. The author examined the exposure in 1975 after completing work on the Slate Islands, and concluded that the breccia was a diatreme (Sage in preparation). In 1977 Mitchell and Platt prepared a brief description of this intrusion along with the Dead Horse Creek structure. The diatreme was recognized as being radioactive by J. Scott (Resource Geologist, Ontario Ministry of Natural Resources, Thunder Bay) in 1976 following staking activity on the Dead Horse Creek structure. The mineral potential of this structure has not been determined. The breccia is radioactive everywhere, but highly variable in intensity. Thorium is dominant over uranium and readings of up to six or seven times background were obtained. Reddish brown carbonate veinlets cutting argillite in the first outcrop west of the trail leading to the diatreme on Highway 17 give readings of one or two times background. The breccia was staked in 1977 by L. Kaye; however, no evidence of prospecting activity was seen by the author at the time of completion of field work in June. The body warrants careful testing to determine the distribution of radioactive mineralization.

Due to lack of outcrop and weathering, samples suitable for analysis are difficult to obtain. Figure 8 (Chart A, back pocket) indicates the location of the matrix-rich specimens selected for chemical analysis, and Table 7 (Chart B, back pocket) gives the analytical results. Figure 9 shows the difference in chemical composition between wall rocks and breccia.

Spectrometer readings for the lithologic units of the McKellar Creek structure are given in Table 8. The lower values for some McKellar Creek units compared to Dead Horse Creek units (see Table 9) reflect less intense alteration and mineralization of the McKellar Creek structure.

An unexpected observation from the spectrometer readings was that the outcrops of the breccia are slightly lower in uranium and thorium than the more weathered breccia re-

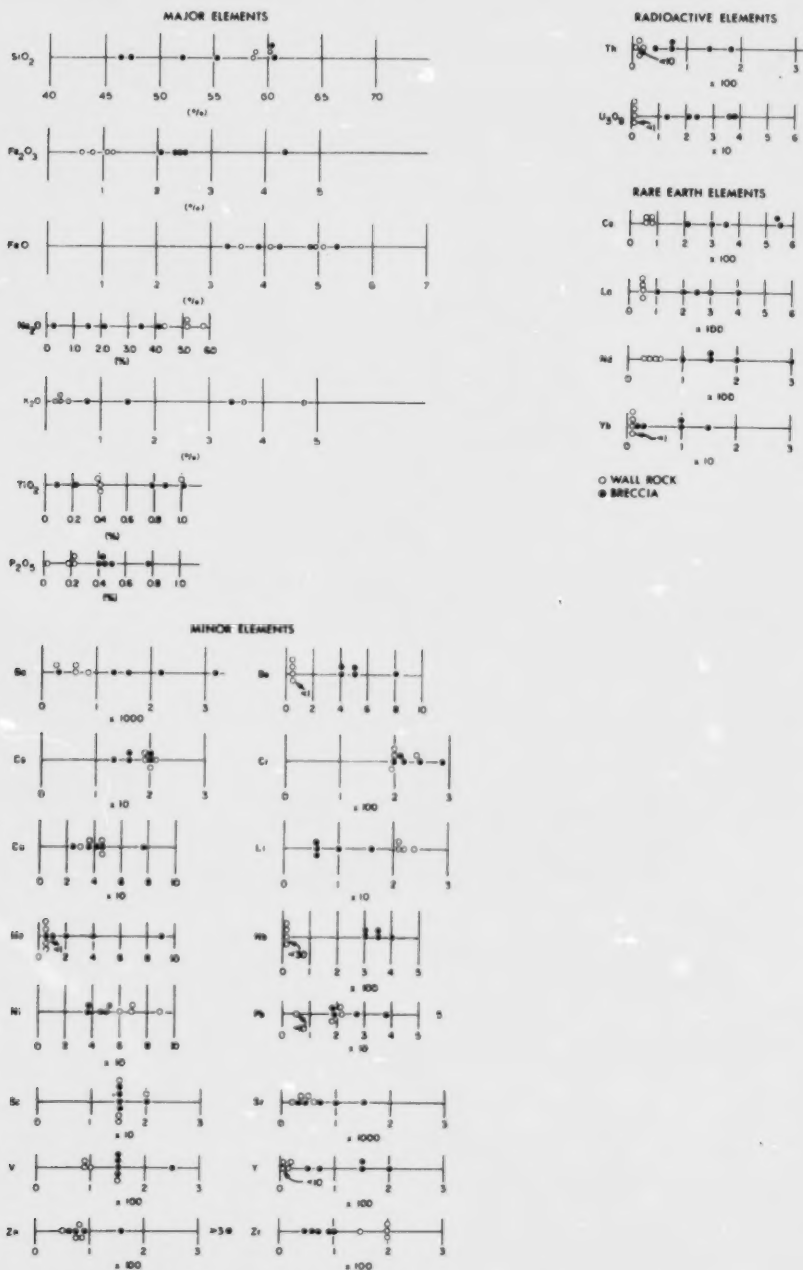


Figure 9. Distribution of major and minor element abundances in wall rock and breccia at McKellar Creek diatreme.

golith exposed during logging operations. This may in part be due to a mass effect, for the readings on the regolith were in hollowed out surfaces, dug by logging equipment; and the outcrop readings were taken on the near vertical faces of the exposure several feet above ground level.

The minor element abundances of Ba, Be, Nb, Zn, U, Th, Sr, rare earths, and P_2O_5 are lower in the Early Precambrian metasediments enclosing the McKellar Creek breccia than in either the McKellar Creek or the Dead Horse Creek breccias (see Tables 7, 9 and Figure 9). Copper, cobalt, chromium and zirconium are about the same in both sample suites, and sodium, lithium, molybdenum, lead, and vanadium are higher in the McKellar Creek wall rock samples relative to the mineralized breccias. More abundant niobium, rare earths, and phosphate in the breccias are indicative of a carbonatite or alkalic rock-carbonatite environment. Anomalous zinc values are typical of uranium-bearing diatremes in the Baker Lake area of the Northwest Territories (Miller 1979), and possibly the Hopi Buttes uranium-bearing diatreme in Arizona (Shoemaker *et al.* 1962). Minor element chemistry supports the model of a carbonatite source for the fluids that altered the breccias, and presumably the initial release of the fluids created the diatreme structures.

The less intense alteration, mineralization, and smaller size of the McKellar structure indicates a less desirable exploration target than the Dead Horse Creek diatreme. If exploration of the Dead Horse Creek structure proves interesting, the McKellar Creek structure should also be tested by a series of inclined drill holes to crosssection the intrusion from contact to contact. By analogy with other diatreme structures, uranium-thorium mineralization may be more concentrated towards the periphery (see 'Recommendations to the Prospector' for details).

TABLE 8. AVERAGED SPECTROMETER READINGS FOR LITHOLOGIC UNITS, MCKELLAR CREEK DIATREME.

Rock type	Number of readings	Average value	
Metasediment	67	T1	3,901
		T2	229
		T3	70
Breccia Regolith	15	T1	15,900
		T2	1,119
		T3	261
Breccia Outcrop	9	T1	16,333
		T2	778
		T3	191
Diabase	2	T1	2,800
		T2	135
		T3	35
Large 2 x 3 m Sibley clast	1	T1	3,000
		T2	150
		T3	100
Lamprophyre	1	T1	2,500
		T2	200
		T3	100

NOTES.

T1 = Th + U + K. T2 = Th + U. T3 = Th.

All readings in counts per minute.

DEAD HORSE CREEK DIATREME

LOCATION AND ACCESS

The Dead Horse Creek structure (Figure 10, Chart A, back pocket, and 3 on Figure 1) is approximately 4 km north of Highway 17 along the Dead Horse Creek access road. This is at approximately 48°50'30''N Latitude and 86°40'25''W Longitude. Access to the complex east and west of Dead Horse Creek is easy from the road. To simplify discussion, the complex has been divided into subcomplexes, but since there is no difference in age between the subcomplexes, all are considered to represent the same event.

General Geology

The Dead Horse complex has maximum dimensions of 1600 by 400 m, and is elongated in a north-northeast direction.

The breccia consists of angular to subrounded clasts of locally derived rocks (Photo 7) in a matrix of comminuted rock debris which has been locally extensively altered. Clasts up to 1 m have been seen, but most frequently they are 0.3 m or less. Mitchell and Platt (1977) reported the presence of Sibley-like clasts similar to those found in the McKellar Creek structure, but the author has not observed such clasts. As with the McKellar Creek structure, no evidence of clast zonation or multiple explosive events was observed. The alteration is extremely variable within the breccia. The first indication of alteration is reddening of clast margins. With more intense alteration, the entire clast is bright brick red and hard to break. Such extensively replaced clasts break with a crude conchoidal fracture. The exten-

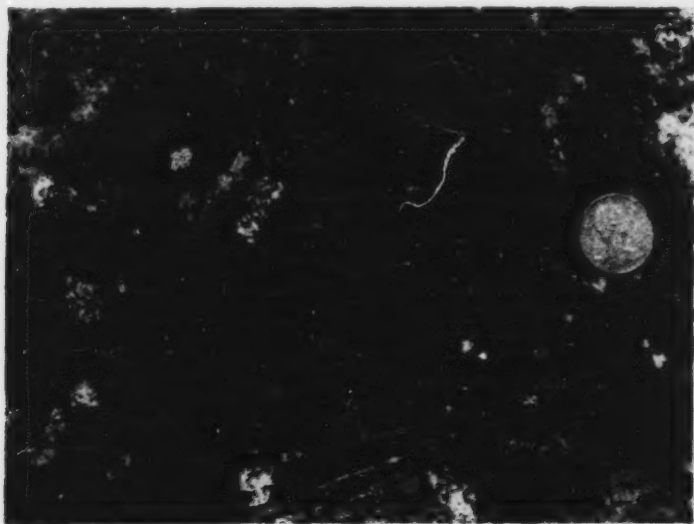


Photo 7. Angular clasts of metasediment weathering in moderate relief over matrix. Note lighter coloured rims than core. Core of clasts weather subdued with respect to rim. Dead Horse Creek diatreme.

sively altered breccias are generally highly radioactive. In the southwest corner and at the west contact of the South Dead Horse subcomplex, are isolated, highly radioactive outcrops of breccia with a carbonate matrix. These outcrops consist dominantly of fine-grained, grey carbonate with isolated red clasts weathering 4 to 5 cm in relief. The clasts have an open framework supported by the carbonate matrix. A lamprophyre dike rich in carbonate cuts the breccia in the face of a cliff in the southwest corner of the complex. The general lack of carbonate within the enclosing wall rocks indicates that the carbonate found in the breccia has been introduced. The author considers the carbonate to be of magmatic origin.

The style of brecciation and type of alteration are identical to altered and fenitized breccias observed by the author at the margins of some carbonatite complexes. In the northeast corner of the south subcomplex is an extensive zone of scapolite replacement. The clasts are not red, but grey on weathered surface. This zone is appreciably more radioactive than the highly altered red breccia. Scapolite is usually identifiable on the weathered surface as white prismatic fibres and on the fresh surface as greenish brown fibres that blend into the matrix. The replacement tends to occur preferentially in the more siliceous metasedimentary clasts. The scapolite weathers out of the clasts giving a worm-eaten appearance to the clasts. The scapolite zone is a more intense zone of alteration than represented by the red breccias. Carbonate, amphibole, and disseminated pyrite are common in the matrix of the scapolite zone, and form part of the replacement mineralogy.

The complex has been cut by dikes of carbonate, diabase, porphyritic trachytoidal diabase, and syenite aplite.

A limited reconnaissance of the Port Coldwell complex by the author showed that dikes cutting the Port Coldwell complex are visually identical to the porphyritic trachytoidal diabase and syenite aplite dikes which cut the Dead Horse breccias. The syenite aplite dikes are nearly always radioactive and have been prospected for their uranium and niobium content within the Port Coldwell complex (private records, Noranda Mines Limited). Walker (1967) considered monzonite and quartz monzonite along the east flank of the diatreme structure to be part of the Port Coldwell alkalic complex. The author has assumed that this correlation is correct. Rb-Sr isochron dating by Bell *et al.* (1979) indicates an isotope age of 1085 ± 15 Ma for the Port Coldwell complex, establishing a maximum age for the diatreme since monzonite occurs as clasts within the breccia.

On the basis of field observations, the author considers the Dead Horse Creek diatreme to be the brecciated and altered top of an unexposed carbonatite intrusion, perhaps younger than the main period of alkalic rock emplacement at Port Coldwell, but older than some diking of that complex. The structure is thus an integral part of the alkalic rock-carbonatite petrogenetic province located north of Lake Superior.

The Dead Horse Creek structure is elongated north-northeasterly, and lies across Dead Horse Creek. Lithologic units cannot be correlated across the creek, indicating the presence of a fault. This interpreted fault may have exerted control on positioning of the diatreme-forming event.

EARLY PRECAMBRIAN

Mafic to Intermediate Metavolcanics

The Dead Horse Creek diatreme cuts a northwest-trending unit of mafic to intermediate metavolcanics. The volcanic unit does not match in width across Dead Horse Creek and thus a fault is inferred along the bed of the creek.

The metavolcanics consist dominantly of dark greenish black, banded amphibolite, pillowed metavolcanics, and massive amphibolite. It is impossible to determine if the banded rocks were originally intrusive or extrusive. The pillowed rocks are extrusive, and the massive units are either sill-like intrusions or the centres of thick flows. The massive un-

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its are slightly coarser grained than the banded amphibolites or pillowed rocks. On fresh surface the metavolcanics are dark greenish black.

The pillow structures are generally deformed, and it is impossible to determine facing directions. The pillows have a dark green selvage 1 to 2 cm wide and are commonly 0.3 to 0.6 m long. Interlayered with the pillowed units are thinly bedded to laminated tuffs. The ridge-like weathering of the tuffs implies the presence of some carbonate enrichment in bands that alternate with more siliceous bands. The bedding is variable in width from less than 1 mm to 1 cm or more. Deformation makes any estimate of width of the tuff unit(s) uncertain, but they appear to be relatively thin (1 to 3 m) units within the largely metavolcanic unit. Garnet porphyroblasts up to 3 mm in diameter weather in relief on rocks of this unit.

Thin sections of this unit were not prepared by the author. The reader can refer to Walker (1967) for petrographic descriptions. Walker (1967) considered the area of the Dead Horse Creek diatreme to lie within the thermal aureole of contact metamorphism of the Port Coldwell alkalic rock complex. On the basis of Walker's (1967) petrographic description, the contact metamorphism would be the hornblende hornfels facies rank of Turner and Verhoogen (1960).

Metasediments

The metasediments weather grey to greenish grey and on fresh surfaces are darker hues of the same colours. Bedding is not common, but where present it is generally 1 to 6 cm in width. On the weathered surface is the occasional bluish quartz grain. The rock commonly has a moderately well developed schistosity defined by the preferred orientation of biotite grains. Biotite is visually estimated to compose up to 20 or 25 percent of the rock. In one exposure of metasediments along the Dead Horse Creek access road on the north side of the complex, graded bedding in a moderately deformed outcrop suggests a north-facing top. On the basis of visual examination, the metasediments were classified as argillite and siltstone. For additional details the reader should refer to the petrographic descriptions of Walker (1967).

Biotite Trondhjemite Dikes

Cutting the metavolcanics and metasediments is a grey, fine to medium grained trondhjemite dike. This dike is schistose and metamorphosed and has likely undergone a tectonic and metamorphic history similar to that of the rocks it cuts. The dike is generally less than 1 m in width, widespread in distribution, but uncommon in occurrence.

In thin section the dike rock is seen to be fine grained, massive to schistose, equigranular, and granoblastic with straight to curved grain boundaries. The mode was estimated to be approximately 15 percent biotite, 35 percent quartz, and 50 percent plagioclase (An_{40} ?). The dike is biotite-andesine trondhjemite.

Granitic Aplite Dikes

In widely scattered areas southeast of the complex, red, fine grained granitic dikes cut the Early Precambrian metasediments and metavolcanics. The dike is locally brecciated and thus has been affected by the diatreme event. The dike rock does not appear to be metamorphosed as does the trondhjemite. The author considers this dike to be Early Precambrian and correlative with the late Early Precambrian phase of more potassic granitic magmatism. In contrast, the grey schistose trondhjemite dike is correlated with the earlier more sodic granitic magmatism. This sequential pattern of granitic intrusion has been observed by the author in many areas of the Canadian Shield (e.g. Thurston *et al.* 1977). By analogy the aplite dike represents the latest phase of Early Precambrian granitic magmatism. The trondhjemite dikes are prekinematic, while the aplite dikes are syn- or post-kinematic.

In this section the texture of the dike rock is seen to be fine grained, massive, microphyritic-seriate, and granoblastic with curved grain boundaries. The freshest sample was visually estimated to contain 35 percent quartz and 65 percent turbid altered feldspar of uncertain composition. The larger microphenocrysts comprise a visually estimated 5 to 10 percent of the rock, and appear to be weakly zoned. Some grains exhibit Carlsbad twinning. The feldspars could not be precisely identified, but some are likely K-feldspar as indicated by what appears to be very fine grained sericite. The turbidity of the feldspar may also be due in part to the presence of clay and/or dusty hematite.

Where this unit has been brecciated by diatreme activity, quartz occurs in lesser amounts and the rock is extensively veined with amphibole. The amphiboles are euhedral to anhedral and colourless to pale green. One specimen with somewhat coarser grained amphibole contains euhedral twinned crystals of amphibole with rare zoning from a pale brownish green core to a less turbid, colourless to pale green rim. Disseminated sulphide is also present in the fractures.

MIDDLE PRECAMBRIAN

Diabase

Along the south flank and portions of the west flank of the diatreme structure is a distinctive massive unit with a diabasic texture. The spatial distribution of outcrops suggests a north trend cross-cutting the stratigraphy. The diabase is altered and moderately brecciated in one exposure, indicating pre-diatreme emplacement. Since this unit clearly cuts the Early Precambrian stratigraphy, and is in turn affected by Late Precambrian diatreme activity, this intrusion is arbitrarily placed in the Middle Precambrian by the author even though an early Late Precambrian age cannot be discounted. The proximity of this unit to the breccia contact along the south and west flank suggests that the dike contact has had at least a local influence on diatreme emplacement. At one location and possibly a second, mapping has disclosed minor offsetting of this unit, suggesting minor post-emplacement faulting. Compass deviation over this unit suggests local concentrations of magnetite.

In this section the rock is seen to be fine grained, massive, equigranular, hypidiomorphic, and subophitic. The mode is visually estimated to be 50 percent plagioclase (An_{36} ?), 40 percent clinopyroxene, 6 percent magnetite, 3 percent amphibole, and 1 percent biotite. The plagioclase forms elongated tabular grains, extensively saussuritized and turbid. Clinopyroxene is anhedral, colourless, interstitial, and locally altered to skeletal magnetite and brownish biotite. Magnetite forms anhedral, interstitial, commonly skeletal grains that are disseminated throughout.

Amphibole occurs in traces as pale green to colourless and brown grains. The amphibole is prismatic and commonly associated with magnetite and biotite. The amphibole may be the product of metasomatic activity associated with hydrothermal alteration of the Dead Horse Creek diatreme, or a breakdown product of the clinopyroxene. On the basis of pleochroism and habit, the author favors the former, for the amphibole appears similar to the sodium-iron rich varieties associated with alkalic rocks.

LATE PRECAMBRIAN

Monzonite to Quartz Monzonite

Walker (1967) mapped a series of granitic rocks along the east flank of the diatreme as syenite to monzonite. Walker (1967) interpreted these rocks as a phase of the Port Coldwell alkalic complex. These rocks clearly cut the Early Precambrian supracrustal rocks and occur as clasts within the diatreme. These rocks are massive, equigranular, and weather buff to pale pink in colour. On fresh surfaces they are pink to pale pink. On the basis of their ap-

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pearance in the field, the author would have difficulty in distinguishing this unit from some late Early Precambrian granitic rocks he has observed. Since Walker (1967) has examined a much larger volume of this unit than the author, the author retains Walker's (1967) age relations. Mapping by Ontario Geological Survey personnel during the 1978 field season along the north flank of the Port Coldwell alkalic complex has outlined similar if not identical rocks (S. Wilkinson, Ontario Geological Survey, personal communication, 1978). The relationship of these rocks to the Port Coldwell complex is unclear, however their spatial distribution appears marginal to the intrusion, (Wilkinson, personal communication). Assuming the inferred relationship is correct, field observations thus indicate diatreme emplacement as later than the main Port Coldwell alkalic rock intrusive event.

In thin section the rock texture is fine to medium grained, massive, equigranular, granoblastic, allotriomorphic with curved to straight grain boundaries. Visually the mode is estimated to be approximately 20 percent quartz, 15 percent amphibole, 15 percent biotite, 10 percent myrmekite, and 40 percent plagioclase. A trace of sphene was noted. On the basis of this one thin section, the author would classify these rocks as amphibole-biotite trondhjemite, but Walker's classification has been retained.

Quartz is anhedral, interstitial, and displays wavy extinction. The interstitial nature of the quartz suggests that it may have been in part introduced. Amphibole is prismatic, anhedral, and varies from yellow brown to pale green. The amphibole in places is poikilitically enclosed within the plagioclase. Biotite occurs as tabular, anhedral, somewhat ragged grains, interlocking with the amphibole. The biotite may also occur enclosed within the plagioclase. Plagioclase occurs as anhedral, interlocking grains and zoning is common. The cores of the grains are commonly saussuritized, and the rims clear, and only weakly twinned. Myrmekite is commonly developed along the edges of some of the grains. Myrmekite also occurs as smaller anhedral grains interstitial to somewhat larger feldspars. The myrmekite consists of wormy intergrowths of quartz and untwinned feldspar.

It is difficult to correlate this rock with the Port Coldwell complex because of the lack of a good primary igneous texture in the sample examined; however the author has adhered to Walker's (1967) interpretation. If not part of the Port Coldwell intrusion, this rock is probably related to the late Early Precambrian period of granitic intrusion, and metamorphosed by the thermal event accompanying the emplacement of the complex.

One specimen of this unit was collected from close to the breccia-monzonite contact. This specimen contains cataclastic zones and pale green to colourless, prismatic amphibole. The amphibole is likely the product of metasomatism accompanying the diatreme emplacement.

Diatreme Breccia

The breccia was subdivided into two rather subjective map-units: non-brecciated to moderately brecciated (map-unit 6b), and moderately to strongly brecciated (map-unit 6a). The actual determination of breccia-wall rock contacts is difficult since both sharp and gradational contacts were observed. The gradational contacts are those where veining and alteration appear to fade away into unaltered, unfragmented rock. Map-unit 6a is subdivided by the author into three subgroups for descriptive purposes. These three subgroups of map unit 6a are all from the area of most intense brecciation and metasomatic alteration.

RED BRECCIA

Red breccia is best exposed at West Dead Horse subcomplex and on the west half of South Dead Horse subcomplex. Less intensely altered exposures are also found at North Dead Horse subcomplex, Central Dead Horse subcomplex, and East Dead Horse subcomplex. The most impressive exposure is a cliff face, approximately 10 m high and 100 m long located in the western portion of South Dead Horse subcomplex.

The breccia is characterized by its bright red angular clasts. While more altered than the McKellar Creek breccias, this subunit appears to be comparable to the McKellar Creek breccia in style of alteration. Clasts within this subunit are up to 1 m, but generally average less than 0.3 m in maximum dimension. Locally, the rims of the clasts are more intensely altered than the centre. Weathering of such clasts leaves a depressed saucer-shaped centre (see Photo 7). The red colour implies introduced iron and the tough, conchoidal fracturing of the clasts indicates silicification. Such breccias also give a strong response to the spectrometer for the potassium spectrum, and thus some potassium may have been introduced. The clasts have a dark green amphibole along their rim and carbonate locally occurs in abundance. Weathering of the carbonate has developed a rough surface on the breccia, and clasts weather in relief over the interclast matrix. Disseminated sulphide is a common accessory within the matrix. The breccia is clast supported.

In thin section the clasts are seen to be very fine grained, granoblastic, turbid, and impregnated with carbonate. The plagioclase composition is sodic andesine. The feldspars are flecked with saussurite and smaller feldspar fragments have been replaced by minor amounts of fibrous amphibole. Very fine grained brown biotite is abundant along the rims of the clasts, and is common within the matrix of the clasts as tiny brown grains in association with carbonate, quartz, and clastic plagioclase. Carbonate occurs interstitial to the clasts. This mineral is anhedral to euhedral in form and is of slightly larger grain size than that replacing the clasts. Interstitial to the carbonate is clear, unstressed quartz into which carbonate crystal faces appear to project. Irregular grains of quartz also occur within the granoblastic textured clasts.

The paragenetic sequence of alteration is biotite, carbonate, and quartz. The amphibole position is uncertain but may precede biotite.

Several euhedral smoky quartz crystals were observed on the upper portion of the cliff face within the South Dead Horse subcomplex. These crystals are approximately 1 cm in length.

A X-ray diffraction pattern of the matrix of one sample gave peaks for calcite, feldspar, dolomite and amphibole (Geoscience Laboratories, Ontario Geological Survey, Toronto).

CARBONATE-RICH BRECCIA

Several outcrops of breccia have relatively high carbonate content (Photo 8). The outcrops are relatively small, and high readings for radioactivity were obtained. The two best examples are located within the South Dead Horse subcomplex. One is near the extreme southwest corner (sample DH 197, Figure 11, Chart A, back pocket) and the other 30 to 40 m west of the cliff face, of red breccia (DH 169). Both exposures are close to the breccia-wall rock contact. A third exposure may be represented by the large blocks of radioactive breccia found along the stream on the east side of North Dead Horse subcomplex (sample DH 386). Solid outcrop was not observed. The relationship of this third outcrop to the complex is uncertain, and it has been tentatively classified as a breccia with a lamprophyre matrix. As with the first two outcrops, this exposure occurred close to, or perhaps at the diatreme-wall rock contact.

The two outcrops in the South Dead Horse subcomplex are characterized by red clasts weathering in pronounced relief above a fine grained, black to grey black carbonate-biotite matrix. The breccia is matrix supported in contrast to most other breccia exposures which are clast supported. The clasts weather up to 4 to 5 cm above the fine grained carbonate-biotite groundmass. The matrix, without the clasts, could pass for one variety of lamprophyre dike, not uncommon to the Port Coldwell area.

In thin section, turbid angular fragments of clastic plagioclase form a minor component. Traces of anhedral, interstitial quartz are present. Small, granoblastic clasts enveloped in carbonate have undergone extensive replacement by carbonate. Brown, very fine grained to fine grained biotite is a major component; some grains are tabular in outline, and others relatively ragged. Very fine grained ragged biotite in places forms narrow rims on

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enclosed carbonatized clasts. Some biotite grains within the carbonate locally enclose small opaque (magnetite?) grains. Carbonate is the major mineral component, and it consists of an interlocking mosaic of anhedral grains. Disseminated accessory opaques are present in minor quantities. The opaques are very fine grained, and in places they occur along the rims of the carbonate-replaced clasts in association with fine grained biotite.

X-ray diffraction patterns of the matrix of this breccia type disclosed the peaks of calcite (dominant), dolomite, feldspar, and mica (Geoscience Laboratories, Ontario Geological Survey, Toronto). A selective spectrographic analysis of sample DH 197, which is almost wholly carbonate, returned 400 ppm Ba, 4600 ppm Sr, and 1140 ppm Ce (Geoscience Laboratories, Ontario Geological Survey, Toronto). The high strontium, barium, and rare earths are typical of magmatic carbonate.

SCAPOLITE REPLACEMENT BRECCIA

Scapolite replacement breccia (Photos 9, 10, 11) is largely confined to the northeastern portion of the South Dead Horse subcomplex. Several small outcrops displaying scapolite replacement were also noted in other areas. One occurrence was observed at the extreme southern end of a weakly brecciated to unbrecciated outcrop located on the west side of the North Dead Horse subcomplex. A second occurrence of scapolite in breccia 0.3 m wide was observed along the south contact of a 1.0 m wide diabase dike cutting the enclosing wall rocks at the edge of a swamp, east of the contact of the Central Dead Horse subcomplex. The diabase dike is lightly reddened by dusty hematite. The dike contains

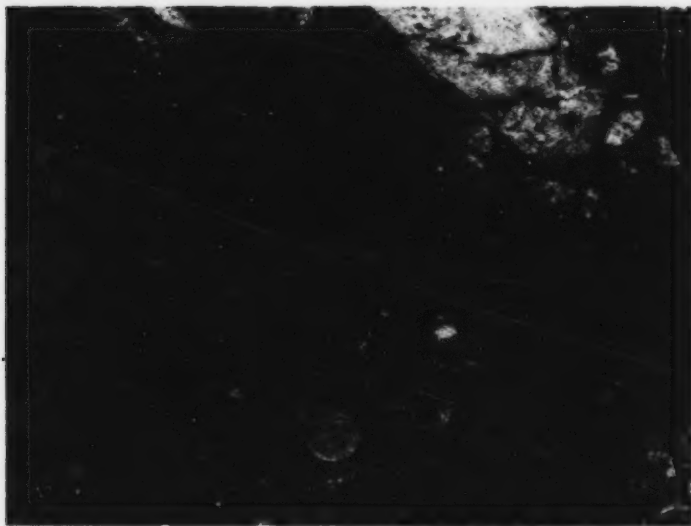


Photo 8. Breccia with high carbonate matrix. Individual angular clasts weather as much as 4-5 cm above the matrix surface. Area has a strong radioactive response. Location P-3, sample DH 197, Dead Horse Creek diatreme.

plagioclase phenocrysts up to 1 cm in length, which constitute a visually estimated 2 to 3 volume percent of the dike.

The main exposures of scapolite replacement breccia are immediately along the east side of the Dead Horse Creek access road, along the north contact of the South Dead Horse subcomplex. This breccia weathers grey and in some places has a jagged rough weathered surface. Clasts range from rounded to angular. The more rounded shape of a number of clasts in this unit may imply more fluid movement and milling of the fragments. Clasts from more massive units tend to be more rounded than those displaying compositional or structural anisotropy. The scapolite is visually identifiable on the weathered surface as white prismatic fibres. These fibres have been observed to be up to 5 cm in length, but they are generally 1 cm or less. On the fresh surface, the scapolite is grey green and blends into similarly coloured clasts and matrix, and is difficult to recognize. Positive identification was made by X-ray diffraction techniques (Geoscience Laboratories, Ontario Geological Survey, Toronto). While replacement may preferentially affect the more siliceous metasedimentary clasts, all compositions of clasts have been observed to have undergone replacement. The scapolite weathers subdued, and weathering of partially replaced clasts imparts a worm-eaten appearance to the outcrop. The matrix consists of amphibole, carbonate, and disseminated sulphide along with scapolite. Weathering of the carbonate matrix in places leaves the clasts higher than the enclosing matrix. Rocks of this unit invariably give a response on the spectrometer.

In thin section, this breccia displays considerable replacement and alteration by carbonate, amphibole and scapolite. The clasts consist of fine grained, turbid, granoblastic

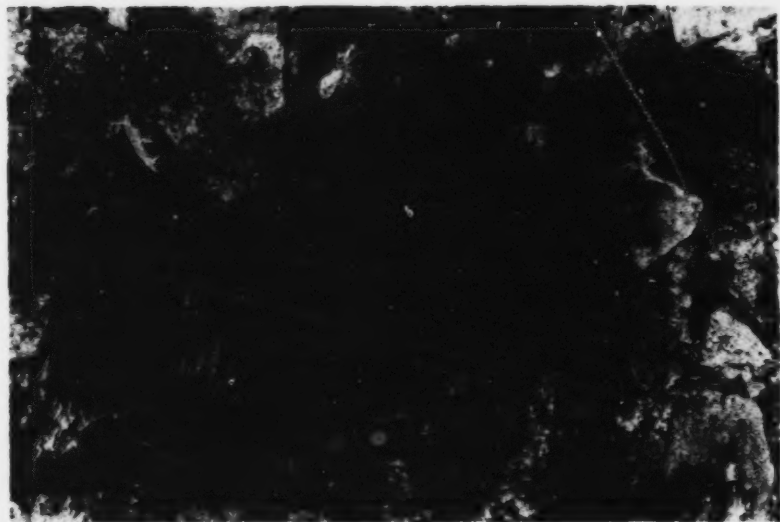


Photo 9. Breccia fragments undergoing concentric alteration. Note angular nature of clasts and local scapolite replacement (pitted area). Most clasts are possible metasediment, the remainder are mostly mafic metavolcanics (not shown). Location P-4, sample DH 224, Dead Horse Creek diatreme.

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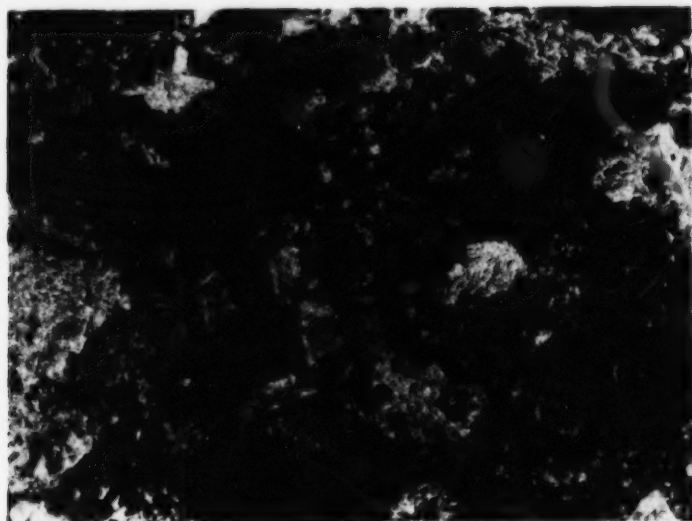


Photo 10. Breccia with jagged, pitted weathered surface from the weathering out of scapolite and some carbonate. Location P-4, Dead Horse Creek diatreme.

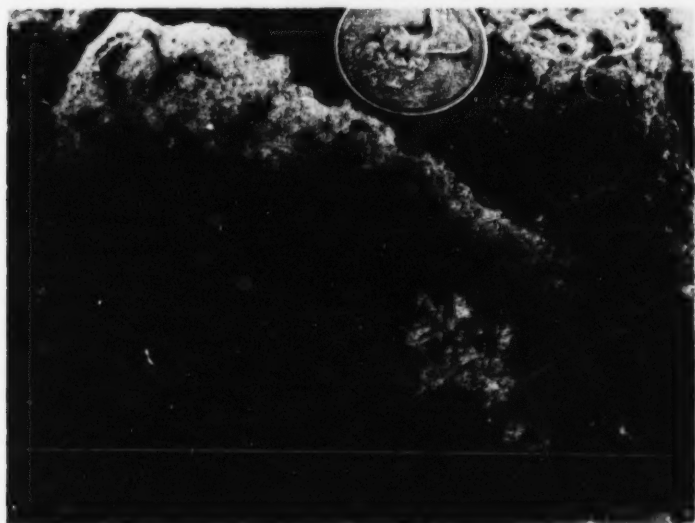


Photo 11. Clast, possibly metasediment, undergoing scapolite replacement. Scapolite is the fibrous white mineral. Location P-4, Dead Horse Creek diatreme.

feldspar, and perhaps traces of quartz. These clasts are extensively altered to very fine grained fibrous amphibole and occasional large grains of poikiloblastic scapolite.

The matrix of the breccia consists of quartz, carbonate, amphibole, opaques, and scapolite. The scapolite occurs as large, optically continuous, prismatic, poikiloblastic grains. The grains are fresh, clear and enclose large areas of fine grained fibrous amphibole. Fractures in some scapolite grains are possibly filled with fine grained fibrous amphibole. Scapolite occurs both in the matrix and in the clasts; rarely do the crystals project into carbonate- and quartz-filled gaps between the clasts.

Amphibole, as very fine grained, fibrous, interlocking masses, is perhaps the most plentiful mineral. It is abundant within the clasts, and the dominant mineral within the matrix. The mineral is colourless to pale green, and locally is stained brown. Coarsening of the grains occurs within the matrix where they project into quartz- and carbonate-filled gaps between clasts. In one specimen the amphibole is distinctly zoned from greenish brown cores to narrow, colourless to pale green rims.

Quartz with wavy extinction forms anhedral, interstitial, polycrystalline aggregates. The quartz locally encloses tiny amphibole grains.

Carbonate, as anhedral grains interlocking with quartz, is not abundant in the matrix. Like quartz, carbonate appears to be late in the paragenetic sequence, and it could be essentially contemporaneous with quartz in deposition.

The opaques are principally sulphide, but some dusty fine grained magnetite may be present. Rusty iron staining, locally streaking the weathered outcrop surface, indicates the presence of the sulphide within the breccia.

On the basis of petrographic observation and indicated mineralogy, the scapolite breccia has had sulphur, iron, carbon dioxide, one of the halogen elements and calcium added. The alteration is consistent with what could be expected from a fluid, analogous to a fenitizing fluid, associated with carbonatite magmatism.

Dike Rocks

A number of dike rocks cut the breccia of the diatreme. The author has completed limited reconnaissance mapping on the Port Coldwell complex, and has visually identified dikes cutting phases of that intrusion that appear identical to those cutting the Dead Horse Creek diatreme. Syenite aplite and porphyritic diabase are two varieties of dike that appear to cut both the Dead Horse Creek diatreme and the Port Coldwell complex. Even if Walker's (1967) correlation of the quartz monzonite to monzonite with the Port Coldwell complex proves to be in error, the presence of identical dike types cutting both the Port Coldwell complex and the diatreme, establishes a maximum Late Precambrian age for the diatreme event.

Various carbonate-rich dikes and lamprophyres also cut the breccia units of the Dead Horse Creek structure. These dike types are more difficult to correlate with ones found at Port Coldwell, but they do appear to be closely similar in texture and mineralogy to some.

DIABASE

Diabase dikes (map-unit 7a, Figure 10) cutting the breccia are most common in the North Dead Horse and Central Dead Horse subcomplexes. The dikes are fine grained, massive, equigranular, and have typical diabasic texture. The dikes are grey black on the weathered surface and black on the fresh surface.

One specimen collected from a dike cutting the Central Dead Horse structure was examined in thin section. The texture of the dike rock is fine-grained, equigranular, massive, and allotriomorphic with curved grain boundaries. The mode was visually estimated to be 55 percent plagioclase (An_{54}), 5 percent opaques, and 40 percent clinopyroxene.

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The plagioclase forms anhedral tabular grains, with spotty, but weak saussuritization. The clinopyroxene is colourless, and is both interstitial to and interlocking with plagioclase. Minor magnetite occurs as an accessory mineral.

LAMPROPHYRE

Lamprophyre dikes (map-unit 7b) are black, fine grained, massive to ribbed parallel to their contacts with the wall rocks, and contain less than 50 percent carbonate. The ribbed dikes are likely the result of differential weathering of dikes which contain varying amounts of carbonate and silicate minerals across their width. These lamprophyres may also represent repeated intrusion of the lamprophyre magma which varied slightly in composition between pulses. They are less than 1 m in width and weather preferentially with respect to the enclosing breccia.

In thin section, the rocks are seen to be very fine grained, massive, and allotriomorphic with curved to straight grain boundaries. The mode is highly variable. On the basis of two samples, the mode was estimated to be 0 to 25 percent amphibole, 10 to 35 percent carbonate, 35 percent or more biotite, and 10 to 25 percent opaques.

Biotite forms small, brown, tabular grains, ragged in outline, and interlocking with other biotite grains and the opaques. Carbonate is anhedral, interstitial, and disseminated throughout the sample. It appears to have been relatively late in the order of crystallization. The amphibole is prismatic, fibrous, and colourless to pale green. The opaques occur as anhedral to subhedral grains, and are disseminated throughout. One specimen contains traces of anhedral and turbid feldspar.

In one specimen, the amphibole forms crudely circular aggregates, perhaps as an alteration product of an unknown mineral. The biotite, opaques, and carbonate are largely interstitial to these circular aggregates.

PORPHYRITIC DIABASE

Porphyritic diabase (map-unit 7c) is a distinctive dike rock which cuts both the breccia and the enclosing Early Precambrian wall rocks. The dike is characterized by green tabular plagioclase phenocrysts up to 3 cm in length, composing 30 to 50 percent of the rock. The phenocrysts are subparallel, imparting a foliation to the rock. This dike type cuts the North Dead Horse subcomplex. The author observed an identical dike rock in a relatively flat lying position near the Bamooos radio tower, north of Knob Lake, and well within the Port Coldwell alkalic rock complex. Since this variety of dike cuts the Late Precambrian, Port Coldwell complex, its presence as a dike cutting the Dead Horse Creek breccia establishes a maximum Late Precambrian age for the diatrema event.

In one thin section the rock is fine to coarse grained, inequigranular, porphyritic-seriate and hypidiomorphic. The mode was visually estimated to be 10 percent plagioclase phenocrysts (An_{53}), 40 percent plagioclase groundmass, 40 percent clinopyroxene, 5 percent opaques, and 5 percent altered glass. On the basis of thin section examination the dike is a diabase porphyry.

The plagioclase phenocrysts are subhedral to euhedral, glomeroporphyritic, tabular in outline, and relatively fresh. The plagioclase of the groundmass forms tabular turbid crystals, that are anhedral to subhedral in outline, and form an interlocking mesh.

Clinopyroxene occurs as anhedral, colourless, somewhat rounded grains interstitial to the plagioclase. Possible former glass is present as irregular patches of iron oxides and chlorite. Opaques form anhedral, disseminated grains throughout the rock.

BIOTITE SYENITE

Biotite syenite dikes (map-unit 7d) cut the breccias of the North Dead Horse subcomplex

and the Early Precambrian rocks east of the South Dead Horse subcomplex. The dikes were originally mapped as syenite aplite but were subsequently identified in thin section as biotite syenite. These dikes are bright red on the fresh and weathered surface, and in places display small (less than 3 mm) K-feldspar phenocrysts which make up less than 1 volume percent of the rock. A spectrometer gives a strong response for potassium; both uranium and thorium are present in detectable amounts relative to the enclosing wall rocks. These dikes are less than 1 m in width.

Dikes which are visually identical cut rocks of the Port Coldwell alkalic complex in several areas. Similar dikes are concentrated at Port Coldwell in the area east of Red Sucker Cove and north of Craddock Lake. Within the Port Coldwell complex, these dikes have been prospected for niobium, uranium, and zirconium (Noranda Mines Limited, personal communication, 1978). A response on the spectrometer was always noted when these dikes were tested.

In thin section the dike rocks are fine grained, massive, inequigranular, microporphyritic-seriate, trachytic, and hypidiomorphic in texture. The mode is visually estimated to be 13 percent biotite, 85 percent K-feldspar, and 2 percent opaques. K-feldspar phenocrysts and quartz are present in trace amounts.

The K-feldspar phenocrysts are euhedral, turbid, blocky crystals with long axes oriented subparallel to the long axes of the groundmass feldspar. The groundmass K-feldspar consists of tabular, turbid, Carlsbad-twinned, subparallel crystals. Narrow rims occur on some crystals which may be relatively clear and fresh in appearance. The subparallel orientation of the feldspar grains defines a trachytic texture which is also well developed in the Port Coldwell dikes.

The biotite occurs as brown interstitial grains. Compared to the Port Coldwell dikes, the one sample examined in this study contains more biotite. Opaques are present as tiny grains disseminated throughout the rock. Minor quartz occurs as clear anhedral grains interstitial to the feldspar.

Petrographically, the rock is a biotite microporphyritic syenite.

CARBONATE-RICH LAMPROPHYRE

Carbonate-rich lamprophyre (map-unit 7e) is highly variable in composition, consisting largely of carbonate and biotite. They weather subdued because of the high carbonate content, and with decreasing carbonate content, they are likely transitional into map-unit 7b. These dikes weather black to grey black and some are ribbed parallel to the dike walls. They are less than 1 m in width. The best exposed example occurs on the face of the breccia cliff on the west side of the South Dead Horse subcomplex. These dikes give a moderate to weak response to a spectrometer, including the potassium spectrum.

In thin section the mode is visually estimated to be 10 to 17 percent opaques, 50 to 70 percent carbonate, and 30 to 40 percent biotite.

The carbonate is turbid and forms an interlocking mosaic of anhedral grains. X-ray diffraction patterns of dike carbonate show peaks for calcite, dolomite, apatite, quartz, and mica (Geoscience Laboratories, Ontario Geological Survey, Toronto).

The biotite occurs as very fine grained, anhedral, ragged to somewhat tabular grains. In one specimen, the biotite forms radiating masses around polycrystalline carbonate in an obvious reaction relationship with some former unknown mineral. The mica in this sample also occurs as very fine grained yellow-brown aggregates throughout the specimen. The biotite in some specimens appears to contain dusty opaque inclusions. In one specimen the mica occurs as small tabular phenocrysts. The grains are anhedral to subhedral, zoned from yellow brown cores to darker reddish brown rims, and display bent to kinked (001) cleavage. The phenocrysts may be xenocrystic.

The opaques are in part euhedral pyrite and in part anhedral magnetite. One sample, in addition to the pyrite and possibly magnetite, displays thin platy unidentified opaques subparallel in orientation. In hand specimen the pyrite grains are up to 1 mm in size.

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Petrographically, the dikes are broadly classified as carbonate-rich lamprophyres.

PORPHYRITIC LAMPROPHYRE

One example of a porphyritic lamprophyre (map-unit 7f) was found where the Dead Horse Creek access road crosses the falls on Dead Horse Creek west of the North Dead Horse subcomplex. A lamprophyre dike of irregular width containing mafic phenocrysts up to 2 cm in diameter cuts metasediments at this site.

In thin section the rock contains an estimated 1 percent apatite, 5 percent biotite-phlogopite phenocrysts, 5 percent amphibole phenocrysts, 10 percent clinopyroxene phenocrysts, 10 percent opaques, and 59 percent carbonate-mica matrix.

The apatite is present as euhedral prismatic crystals. The biotite-phlogopite phenocrysts are anhedral to subhedral in outline, with the larger crystals displaying kink banding and bent (001) cleavage. The phenocrysts are zoned from pale yellow-brown cores to brown, reddish-brown rims. The amphibole forms large subhedral brown to pale brown crystals which in places enclose both carbonate and traces of fine grained opaques. The rims of the grains are darker brown than the core, and reflect a zonation of the crystals. Clinopyroxene occurs as colourless, extensively altered, ragged grains. The alteration occurs along cleavage planes and consists of very fine grained fibrous amphibole. The pyroxene grains have an overall rounded outline; and traces of very fine grained biotite may occur along the edges, roughly outlining the pre-alteration shape of the grain.

The matrix consists of a very fine grained interlocking aggregate of mica and carbonate. Disseminated opaques occur throughout the sample as tiny anhedral grains. Some magnetite may be an alteration product of the pyroxene; several grains were enclosed in the biotite-phlogopite phenocrysts.

The pronounced kinking of the biotite-phlogopite suggests the possibility that the mica is xenocrystic. The alteration and reaction rims imply a disequilibrium set of conditions. This lamprophyre may be transitional to the microporphyritic lamprophyre (map-unit 7e).

METAMORPHISM-METASOMATISM

The Dead Horse Creek diatreme lies within the thermal aureole of the Port Coldwell alkaline complex (Walker 1967). On the basis of visual examination, the enclosing rocks have been metamorphosed to the amphibolite facies rank of regional metamorphism, or hornblende hornfels facies rank of contact metamorphism (Turner and Verhoogen 1960).

Metasomatism is visually evident throughout the complex. The pronounced reddening of the breccias indicates the addition of hematite dust, and the cherty nature of some of the breccias indicates the addition of silica. The potassium spectrum on the spectrometer generally gives a moderate to strong response indicating that potassium has been added to the breccia. However, a comparison of the sodium content of the breccia with enclosing wall rocks indicates moderate to strong sodium depletion. The ubiquitous carbonate within the breccia suggests the addition of carbon dioxide and possibly calcium. The fibrous amphiboles, by analogy with other amphiboles observed by the author during the study of alkaline rock-carbonate complexes (Sage, in preparation), are likely of the sodium-iron-calcium variety. The presence of disseminated sulphide indicates that sulphur was available, and the scapolite zone suggests one of the halogen elements was also present.

Chemical analyses of the breccias, when compared with analyses of enclosing wall rocks (Table 9, Chart B, back pocket, Figure 12), indicates higher contents of uranium, thorium, niobium, rare earths, and beryllium.

The analytical data for both the McKellar Creek and Dead Horse Creek diatremes (see Tables 7, 9 and Figures 9, 12) would upon first appearance suggest silica depletion rather than addition. This apparent depletion is misleading and it is largely a function of relative carbonate content of the breccia matrix. Those specimens with lowest silica content con-

sist predominantly of carbonate with isolated clasts. The breccias with higher silica represent more clasts and less carbonate. The proposed addition of silica is based on the observation that the red breccias break with a subconchoidal fracture, display a saucer-shaped weathered surface with depressed centres and raised rims, rare euhedral quartz crystals in the matrix, and the local presence of clear interstitial quartz in the matrix. While the author favours silica addition, silica remobilization rather than addition cannot be discounted on the basis of either field or petrographic evidence.

The chemical data suggest iron addition at McKellar Creek, however the data are less conclusive for Dead Horse Creek. The inclusion of several mafic metavolcanic samples in the Dead Horse Creek background samples has given rather high averages to the reference base. The deletion of the mafic metavolcanics and consideration only of the metasediments suggests iron addition. At McKellar Creek the wall rock is exclusively metasediment and at Dead Horse Creek it is dominantly metasediment. Comparison of these data would also suggest iron addition at Dead Horse Creek.

At both McKellar Creek and Dead Horse Creek the increase in ferric iron is well demonstrated by the chemistry (Tables 7 and 9). The increased oxidation of iron is characteristic of a fenitization process (Vartiainen and Woolley 1976) and is the likely cause of the reddening of the McKellar Creek breccia and the red breccias at Dead Horse Creek.

The chemical data suggest a nine to ten fold increase in the potassium content of the breccias over that found in the wall rocks.

Table 10 is a summary of the chemical differences observed between mineralized and unmineralized samples from the McKellar Creek, Dead Horse Creek, and Slate Islands diatremes. The Slate Islands breccias were not analyzed for SiO_2 , Fe_2O_3 , FeO , and K_2O . There was no visual or petrographic evidence of silica addition, the matrix was highly contaminated with Gunflint iron formation, and spectrometer readings indicated no addition or removal of potassium.

The dominant pattern of iron, silica, and potassium enrichment, the presence of carbonate, and the anomalous niobium, thorium, uranium, and rare earths is analogous to metasomatic alterations accompanying carbonatite emplacement. In the case of the Dead Horse Creek diatreme, the fluids were depositing silica, not removing it, as is the case in sodium fenitization typical of most Ontario carbonatite intrusions. The fluid reacting with the breccia was likely originally equivalent to a fenitizing fluid which had been modified from its original composition by more proximal reaction (sodium fenitization) in association with a carbonatitic magma. This modified fluid then reacted with the diatreme breccia, depositing its load in a distal setting.

In a study of the E. kusu carbonatite complex, Uganda, Baldock (1973) reported the introduction of silica accompanying potassium metasomatism in the outer regions of a potassic fenite aureole. He considered the silica to be derived from the inner de-silicated part of the aureole. Vartiainen and Woolley (1976), after a detailed study of fenites at the Sokli carbonatite intrusion, Finland, concluded that potassic fenitization is distal to the carbonatite complex and represents a lower temperature of alkali metasomatism than sodic fenitization. Both Baldock (1973) and Vartiainen and Woolley (1976) considered potassic metasomatism to be characteristic of high level, lower temperature alteration. Consequently sodic metasomatism, typical of Ontario carbonatites represents a deeper level, more proximal, higher temperature form of alteration.

The breccia of the Dead Horse Creek diatreme is considered by the author to be the result of explosive release of volatiles associated with the emplacement of volatile-rich carbonatite magma at depth, and to have been subsequently metasomatized by fluids originating from this magma. The Dead Horse Creek diatreme structure would therefore lie above an unexposed carbonatite intrusion. The brecciation accompanying volatile release and emplacement developed a plumbing system in rocks lacking in permeability or porosity, allowing ready access to fluids associated with the magma. These carbonatite-derived fluids and volatiles transported and deposited the elements of economic interest, and caused the metasomatic alteration and replacement of the breccias.

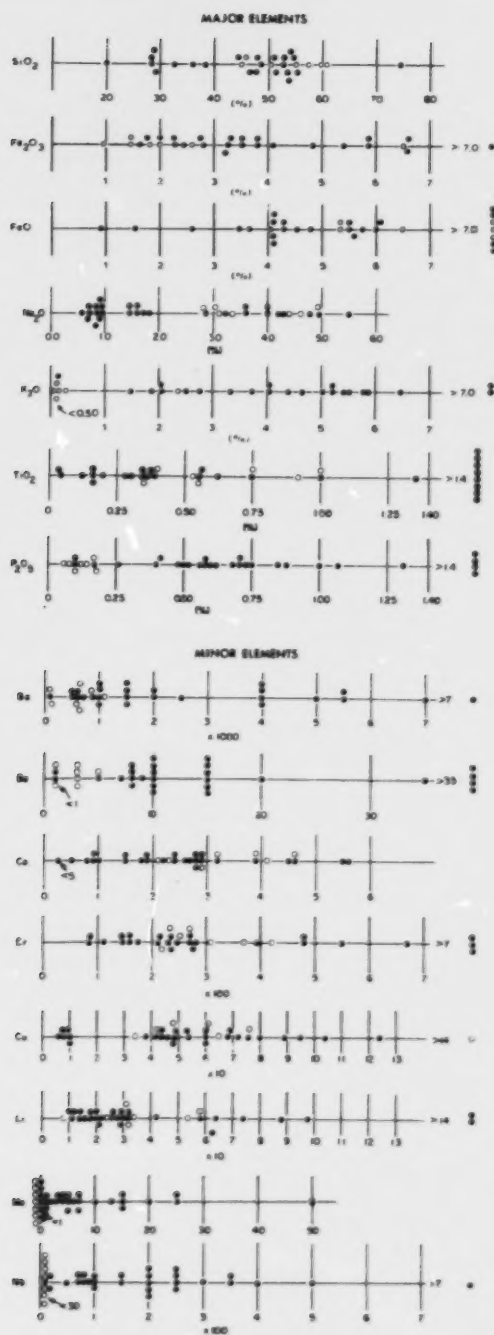
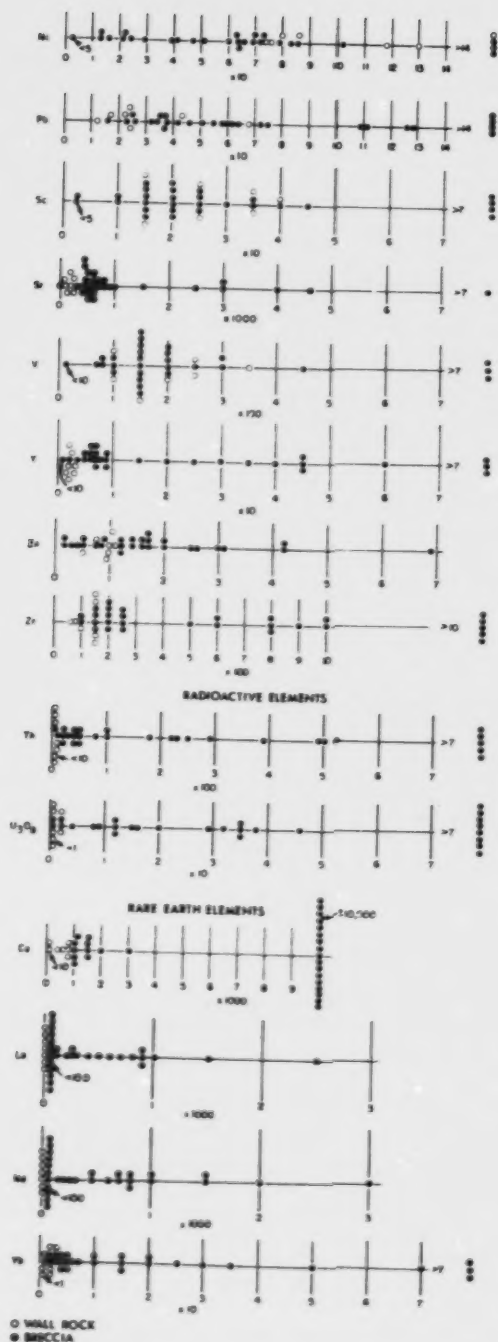


Figure 12. Distribution of major and minor element abundances in wall rock and breccia at Dead Horse Creek diatreme.



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TABLE 10. MAJOR AND MINOR ELEMENT ABUNDANCES IN DIATREME BRECCIAS WITH RESPECT TO WALL ROCKS. SEE ALSO TABLES 4, 7, 9 (CHART B, BACK POCKET).

	Addition	Depletion	Relatively unchanged
Dead Horse Creek	Ba, Be, Cr, K, Mo, Nb, Pb, Sr, Sc, Y, Zn, Zr, Ce, La, Nd, Yb, U ₃ O ₈ , Th, P ₂ O ₅ , TiO ₂ , SiO ₂ , Fe ₂ O ₃	Li, Na ₂ O, FeO	Co, Cu, Ni, V
McKellar Creek	Ba, Be, K, Mo, Nb, Pb, Sr, Y, Zn, Ce, La, Hf, Yb, U ₃ O ₈ , Th, P ₂ O ₅ , SiO ₂ , Fe ₂ O ₃	Li, Na ₂ O, Ni, Zr, FeO	Co, Cr, Cu, Sc, Y, TiO ₂
Slate Islands	Co, Cr, Mo, Ni, Pb	Ba, Li, Sr, Zr, P ₂ O ₅ , Na ₂ O	Be, Cu, K, Nb, Su, V, Yb, Zn, Ce, U ₃ O ₈ , Th, La, Ni, SiO ₂

NOTE:
Silica addition or depletion based on field and petrographic observations and not breccia chemistry.

Carbonatites are considered to be of mantle origin (Powell *et al.* 1966, Wyllie and Huang 1976) and thus the elements of economic interest are considered by the author to be also of mantle origin, derived from magmatic processes associated with carbonatite generation and emplacement.

On the basis of geological data the author considers the Dead Horse Creek diatreme to likely be coeval with the uraniferous Prairie Lake carbonatite which contains significant concentrations of uranium-bearing pyrochlore (Sage 1975). The Prairie Lake carbonatite has been dated by Rb-Sr techniques at 1033 ± 59 Ma (Bottrill 1975).

Structural Geology

The breccia structure is approximately 1600 m long and up to 400 m wide, and comprises three subcomplexes. West of the south subcomplex is a minor subcomplex approximately 60 m long and 15 m wide which is referred to as the West Dead Horse subcomplex. East of the north subcomplex is another small subcomplex, approximately 240 by 60 m with a northwest-striking long axis, and referred to as the East Dead Horse subcomplex. The main breccia zone has a trend east of north, however the small western and eastern structures are elongated in a northwest direction. These small structures may occupy small faults cross-cutting the Early Precambrian rocks enclosing the main structure.

The main structure appears to cross Dead Horse Creek at a shallow angle with most of the structure lying east of the north-south trending creek. The author was not able to correlate lithologies across the creek, and would concur with Walker (1967) that the creek is occupied by a fault. This fault is referred to as the Dead Horse Creek Fault, and may represent the structure controlling the emplacement and northeast trend of the diatreme intrusion.

A number of small faults occur marginally to the breccia. It is uncertain whether these faults cut the breccia, or existed prior to breccia emplacement and exerted control on the

emplacement. The author suspects that these faults are older than the breccia, and that they may have been re-activated. However no fault has been traced completely through the breccia.

Within the south subcomplex, the more centrally located outcrops are limited in number but appear to be less brecciated and less altered than more marginal exposures. The core of the structure may therefore be less brecciated and altered than the periphery. The author has obtained more intense radioactivity readings on the spectrometer in a similar spatial distribution. Within the central and northern subcomplexes, less intense brecciation and alteration may be located towards the margins.

The south margin of the West Dead Horse structure is sheared and brecciated, and locally, sheared and brecciated rock hosts the high grade uranium-thorium mineralization of this subcomplex. While some breccia-wallrock contacts are sharp, others are more gradational as brecciation and alteration fade into unaltered rock.

Along the southern and western flanks of the South Dead Horse subcomplex, the massive diabase unit may have exerted local control on emplacement of the breccia.

Geophysical Expression

The diatreme structures along the north shore of Lake Superior lack distinctive aeromagnetic expression (ODM-GSC 1963). This may be due to the wide flight line spacing relative to the small size of the structures.

Recommendations for Future Study

To gain an understanding of the origin of the Dead Horse Creek structure, and to better define its uranium potential, future studies should include detailed microprobe analysis of the mineral phases and fluid inclusion studies. Such work is needed to determine fluid compositions and to define the physical conditions under which they existed and metasomatized the breccias. A more quantitative study of the alteration of the breccias is also warranted.

Economic Geology

Mitchell and Platt (1977) published a brief report on the structure. The Dead Horse Creek diatreme was discovered in 1977, and staked on behalf of Gulf Minerals Canada Limited. In 1977 and 1978, pitting was completed on the West Dead Horse structure. During 1978 Gulf Minerals Canada Limited completed line cutting over the breccia, and detailed geologic mapping was started. In the fall of 1978 the company completed eight diamond drill holes totalling 944 m.

The Dead Horse Creek structure has the greatest economic potential of any diatreme structures yet identified on the north shore of Lake Superior. The author has obtained spectrometer readings 10 times background in some areas. Thorium appears to dominate over uranium. A selected group of samples was submitted for analysis (see Table 9), which disclosed anomalous quantities of uranium, thorium, rare earths, beryllium, and in one instance zirconium. Base or precious metals previously reported by Fenwick and Scott (1978) were not found in significant quantities. The silver-lead mineralization reported by Fenwick and Scott (1978) was likely from an accidental clast of mineralized rock derived from lead-silver-zinc veins that cut the Early Precambrian rocks of the area (Walker 1967). With perhaps the exception of beryllium, the anomalous metal contents are diagnostic or characteristic of a carbonatite.

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The breccia samples analyzed contained a relatively high volume of clasts even though samples were selected to give the highest matrix content possible. Therefore, the breccia matrix, which is expected to contain the values of interest, might run several orders of magnitude higher in the elements of interest if all the clasts could be removed. Since the clasts cannot be removed during extraction, they act as a diluent to the mineralization and lower the overall grade and economic potential.

The presence of both niobium and uranium suggests that some of the uranium may be held in pyrochlore even though the author could not find pyrochlore in the thin sections studied. Pyrochlore with uranium is the host for radioactive mineralization at the Prairie Lake carbonatite (Sage *et al.* 1976b) which may be of the same age as the Dead Horse structure.

Thin sections were prepared from samples collected from pits along the southwest flank of the West Dead Horse subcomplex. The samples are strongly radioactive and returned the best assay values within the suite analyzed. In hand sample the mineral of interest is chocolate brown and has a conchoidal fracture with vitreous lustre. Traces of bright-yellow uranium stain rarely occur along fractures. Thin sections show a mortar structure due to angular mineral fragments, and suggests that the mineralization at Dead Horse West likely occupies a shear zone located along the south contact of the subcomplex with the wall rocks.

In thin section one sample containing the chocolate brown glassy mineral consists of 40 percent isotropic, brown, turbid unidentified mineral, 40 percent grey, turbid, angular to subangular feldspar fragments, 10 percent carbonate, and 10 percent unknown mineral. The unknown mineral consists of rounded grains, yellowish brown in colour, turbid, and of moderate relief. The turbidity of the mineral and/or rock is likely the result of the presence of dusty hematite.

X-ray diffraction on a selected sample of the glassy material failed to give a definitive pattern. A heated specimen gave a weak pattern somewhat similar to pyrochlore (betafite), however, the specimen contains relatively little niobium and is not likely a member of the pyrochlore group. Analysis of this same specimen returned 400 ppm niobium, 6800 ppm U_3O_8 , and 4770 ppm thorium. The sample also ran in excess of 1 percent beryllium and in excess of 3 percent zirconium. Detailed mineral studies at the Royal Ontario Museum have identified the beryllium-bearing mineral as phenacite (S.B. Lumbers, Curator of Geology, Royal Ontario Museum, 1979, personal communication). Phenacite is a beryllium silicate, usually considered to be more or less exclusive to pegmatites. The turbid, yellowish brown coloured, unknown mineral previously observed in thin section is undoubtedly phenacite, since it was the only mineral occurring in abundance that was not readily identifiable. The mineral or minerals containing the uranium, thorium, and zirconium have so far remained unidentified. The uranium-thorium mineralization of the Dead Horse breccias will require much additional study before positive identification of the minerals can be made.

Figure 11 (Chart A, back pocket) indicates the location of assay samples; Table 9 gives the assays for a number of the above samples. Table 11 lists spectrometer readings for various rock types at Dead Horse Creek, and Table 12 gives spectrometer readings for specific sample locations at West Dead Horse subcomplex.

Comparison of minor element abundances in the Dead Horse Creek diatreme and its wall rocks (Table 9, Figure 12) shows that in addition to U, Th, and Be, other elements (Ba, Sr, Nb, Pb, rare earths, phosphorous, and titanium) are enriched in the diatreme. The anomalous niobium, rare earths, phosphorous, and titanium imply a relationship to alkalic rock-carbonatite magmatism. Erratic, but slightly higher Pb, V, Co and Mo are indicated. Chromium and zinc appear relatively the same, and copper values are erratic. Lithium and possibly nickel appear depleted.

On the basis of both geology and minor element chemistry, a relationship to carbonatitic magmatism is indicated. The diatreme structure and alteration are likely the result of fluids associated with carbonatite emplacement. The diatreme may be the fractured and altered top to a unexposed carbonatite intrusion. The similarity in alteration type, and en-

**TABLE 11. AVERAGED SPECTROMETER READINGS FOR
THE DEAD HORSE CREEK DIATREME AND
ASSOCIATED ROCKS.**

Rock type	All recorded data			All recorded data minus rejected high values		
	No. of readings		Aver- age	No. of readings		Aver- age
Mafic to intermediate metavolcanics	86	T1	3,462	77	T1	2,638
		T2	199		T2	164
		T3	50		T3	46
Laminated tuff associated with metavolcanics	3	T1	1,400			
		T2	69			
		T3	42			
Metasediments	138	T1	4,256	132	T1	4,064
		T2	238		T2	231
		T3	56		T3	54
Breccia	172	T1	14,185	160	T1	10,945
		T2	6,977		T2	5,488
		T3	179		T3	136
Trondhjemite	3	T1	3,000			
		T2	163			
		T3	41			
Lamprophyre dikes	3	T1	19,333		Readings erratic	
		T2	2,327			
		T3	712			
Aplite (Early Precambrian)	5	T1	11,120		Readings erratic	
		T2	506			
		T3	136			
Diabase (Late Precambrian)	14	T1	3,650		Readings consistent	
		T2	189			
		T3	52			
Diabase (Middle Precambrian)	15	T1	3,087	13	T1	2,754
		T2	154		T2	145
		T3	43		T3	43
Trondhjemite (Late Precambrian)	19	T1	5,105	15	T1	4,533
		T2	275		T2	252
		T3	66		T3	59
Syenite (Late Precambrian)	4	T1	12,250		Readings erratic	
		T2	705			
		T3	165			
Porphyritic Diabase (Late Precambrian)	3	T1	5,667		Readings consistent	
		T2	280			
		T3	69			

NOTES.

All readings in counts per minute.

T1 = Th + U + K. T2 = Th + U. T3 = Th.

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richment in minor elements characteristic of carbonatite magmatism in both the McKellar Creek and Dead Horse Creek diatremes, suggests a similar mode of occurrence and implies a similar age. At least some of the anomalous minor metal concentrations are similar to those found in the Hopi Buttes uraniferous diatremes in Arizona, U.S.A. (Shoemaker *et al.* 1962).

The calculated averages for spectrometer readings given in Table 11 should be used with caution. Mapping into the wall rocks was limited. Within the mafic metavolcanics, erratic anomalous readings were obtained in proximity to the breccia, and in the area between South Dead Horse and Central Dead Horse subcomplexes. The anomalous readings were generally on the T1 scale indicating the presence of anomalous potassium. Even though visual alteration and brecciation were absent, the readings may reflect potassium metasomatism along joint surfaces by fluids accompanying breccia alteration. Also, the unaltered homogeneous-looking rocks in proximity to the diatreme may be large blocks enclosed by unexposed breccia dikes, and have been subjected to minor pervasive po-

TABLE 12. SELECTED SPECTROMETER READINGS AT HIGH GRADE SHOWING AT WEST DEAD HORSE SUBCOMPLEX (SEE TABLE 9, CHART B, FOR ASSAYS OF SELECT SAMPLES).

Location	Readings	Remarks
DH127	T1 20,000	Sheared rock.
	T2 1,100	
	T3 350	
DH128	T1 off scale	Sheared rock, trace of U staining.
	T2 30,000	
	T3 11,000	
DH129	T1 5,500	Granitic aplite immediately north of high grade showing.
	T2 320	
	T3 55	
DH130	T1 off scale	Sheared rock.
	T2 10,000	
	T3 2,300	
DH131	T1 off scale	Sheared, brecciated, and silicified.
	T2 3,300	
	T3 1,100	
DH132	T1 off scale	Red, silicified, hematized breccia.
	T2 10,000	
	T3 3,300	
DH133	T1 5,500	Metasediments enclosing shear zone. Unsheared, unmineralized.
	T2 300	
	T3 55	
DH134	T1 20,000	Red, silicified, hematized breccia.
	T2 1,500	
	T3 260	
DH135	T1 5,000	Metasediments enclosing shear zone. Unsheared, unmineralized.
	T2 350	
	T3 60	

NOTES.

All readings in counts per minute.

T1 = Th + U + K. T2 = Th + U. T3 = Th.

tassic metasomatism which is not visually recognizable. A similar pattern of erratic values was encountered in the metasediments, but it was not nearly as intense or widespread.

The average breccia value simply indicates the presence of anomalous potassium, uranium and thorium. Readings on these rocks are highly erratic, varying from typical metasediment-metavolcanic values to values of several tens of thousand. The averages calculated without including the high and likely spurious readings are likely to be more representative.

RECOMMENDATIONS TO THE PROSPECTOR

Mapping by the author disclosed two areas within the south subcomplex that possibly warrant drilling. One area is in the southwest corner, the second in the northeast corner. Both areas represent extensive alteration and relatively high radioactivity, with readings up to and locally exceeding 10 times background. Drilling of some areas for geologic data may be advisable. Remaining areas of the diatreme warrant close and systematic prospecting. Within the South Dead Horse subcomplex, uranium and thorium mineralization may be concentrated towards the periphery of the complex, in a manner similar to some occurrences at Hopi Buttes (Shoemaker *et al.* 1962) and the Orphan mine (Gornitz and Kerr 1970). Both deposits occur in diatreme structures in Arizona.

Shearing along the south flank of the West Dead Horse subcomplex contains uranium, thorium, beryllium and zirconium. The chocolate brown, glassy mineral(s) containing the uranium values have not been identified. The enclosing schistose supracrustal rocks are relatively impermeable. Shear zones marginal to or radiating from the structure may offer particularly favorable sites for the concentration of mineralizing fluids, and thus for high grade concentrations of the elements of interest.

The low ground between the West Dead Horse Creek subcomplex and the South Dead Horse Creek subcomplex may warrant testing for the extension of the high grade uranium mineralization at the West Dead Horse subcomplex.

REGIONAL STRUCTURAL SETTING

The following discussion pertains to the Slate Islands, McKellar Creek, and Dead Horse Creek diatremes. The relationship of the Gold Range diatreme to regional geology is uncertain. The Neys diatreme is considered by the author to represent the release of high level accumulation of volatiles in a crystallizing alkalic magma, entirely different from the other structures, which represent mantle-derived volatiles. The volatiles of the Dead Horse structure were related to carbonatite intrusion, and in the case of the Slate Islands, perhaps, diabasic or gabbroic intrusion.

Figure 13 is a generalized sketch of major alkalic geologic features and structures associated with these features north of the Lake Superior basin. The Slate Islands occur at the junction of two regional faults (Figure 13) identified on the basis of geophysical data by Hinze *et al.* (1966). The Michipicoten Island fault passes south of the islands, and up along the southwest side of the island group, and is likely a curvilinear feature marginal to the Lake Superior basin. The Big Bay - Ashburton Bay fault crosses the Lake Superior basin on a northeast trend intersecting the Michipicoten Island fault immediately south of the Slate Islands. It continues northeastward, intersecting the shoreline in the area of Ashburton Bay along the west flank of the Port Coldwell complex. The Big Bay - Ashburton Bay fault is actually a zone of faulting, which, at its point of impinging on the mainland between the Slate Islands and Ashburton Bay, spans a width on the order of 30 km between Ashburton Bay and Jackfish Bay north of the Slate Islands. The north- to east-of-north trending linears along the shoreline, that are commonly occupied by small streams, are a reflection of a series of subparallel shears and faults. On the basis of airphoto interpretation and topographic maps, the author has postulated the extension of the fault northward to the Killala Lake alkalic rock complex, and then beyond to the Chipman Lake fenites and carbonatite dikes (Sage 1978). Subsidiary faults possibly controlled the emplacement of the Prairie Lake carbonatite (Sage 1978). At Chipman Lake, the fault has a left lateral offset of approximately 0.8 km (Sage *et al.* 1976a). South of Lake Superior, this structure has been traced into Michigan and Wisconsin (Klasner and Turner 1973, Klasner *et al.* 1975). The Big Bay - Ashburton Bay structure is the site of considerable crustal thickening (Smith *et al.* 1966; O'Brien 1968), and divides the Lake Superior basin into sub-basins, indicating that the structure was a topographic high in Late Precambrian time (White 1972). At the site of the Slate Islands, the trend of the Big Bay - Ashburton Bay fault swings east, and in the proximity of the Port Coldwell complex, it swings west. Perhaps these deviations in trend created points of dilatancy during movement, thereby controlling the site of the Slate Islands diatremes and Port Coldwell alkalic rock complex (Sage in preparation). North to northeast trending fractures, parallel and subsidiary to the main structure, likely controlled the emplacement of the McKellar Creek and Dead Horse Creek diatremes, and account for their long axis orientation. The Killala Lake alkalic rock complex occurs at the point of intersection of the extension of the Big Bay - Ashburton Bay fault, and a southwest trending lineament, conformable to lithologic trends (Coates 1970), between the Killala Lake alkalic rock complex and Prairie Lake carbonatite. Most of the alkalic rock-carbonatite intrusive events are Late Precambrian in age, however, a middle Paleozoic age for the Slate Islands lamprophyre dike with carbonatite affinities suggests that alkalic magmatism, north of Lake Superior, along this trend, spanned at least 700 Ma.

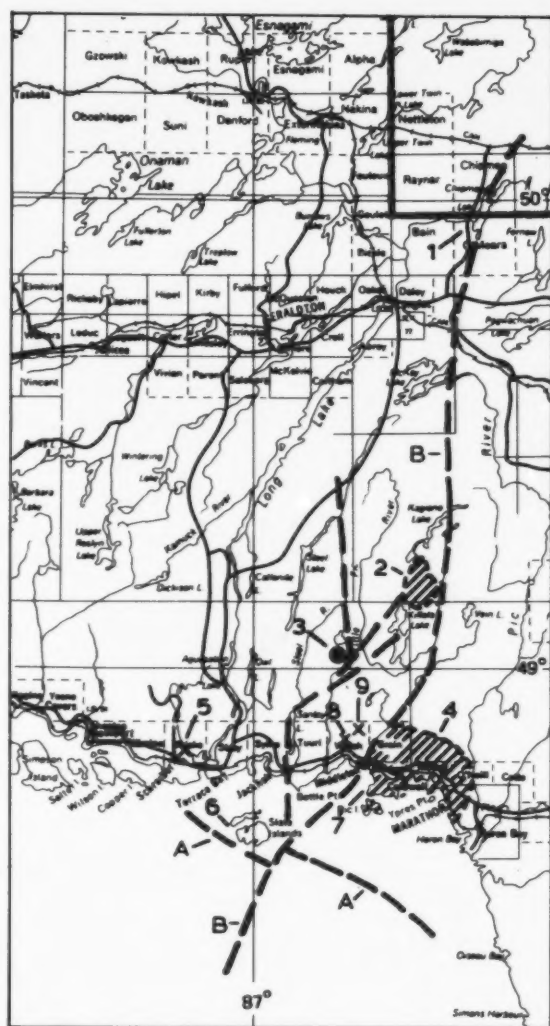


Figure 13. Major carbonatite-alkalic intrusions and major regional faults. 1) Chipman Lake fenites and carbonatite dikes; 2) Killala Lake alkalic complex; 3) Prairie Lake carbonatite; 4) Port Coldwell alkalic complex; 5) Gold Range diatreme; 6) Slate Islands diatremes and carbonatite dike; 7) Neys diatreme; 8) McKellar Creek diatreme; 9) Dead Horse Creek diatreme. A) Michipicoten Island fault; B) Big Bay - Ashburton Bay fault and its extrapolated northern extension. Scale 1:1,584,000.

DIATREME EMPLACEMENT

Breccias, as intruding dike-like bodies and as columns of more or less circular to elliptical cross section, are a common geological feature in some areas outside the Canadian Shield. Mineralized breccia pipes are common in the mining districts of the Western Cordillera, and the literature is so profuse that it would be difficult to briefly summarize. Most, if not all, of these breccia pipes are high level magmatic expressions of the emplacement of felsic rocks and associated volcanic activity. Base and precious metal mineralization is the dominant economic interest in these pipes, while uranium-thorium mineralization is absent. Models proposed for diatremes associated with magmatic activity of felsic composition do not appear to be directly applicable to diatremes found on the north shore of Lake Superior, the possible exception being the Neys diatreme. The Neys structure is minor and appears to be mostly of academic interest. The present discussion will thus be concerned with the larger diatreme structures found on the Slate Islands, and at Dead Horse and McKellar Creeks. For the Neys diatreme, the reader should refer to the model of Norton and Cathles (1973) for a possible detailed explanation. These investigators proposed that volatiles collect in apical regions of a pluton beneath a cooled rind; the rind is then pierced and brecciated. This model is suitable for the breccia pipes found in association with porphyry copper deposits; which have formed during emplacement of the associated felsic plutons. Breccia pipes of this model are a high level manifestation of this type of magmatic activity, and are likely to terminate downwards at relatively shallow depth. The volatiles forming breccia pipes of this type are likely to be largely of crustal origin, while the volatiles associated with the Slate Islands, McKellar and Dead Horse Creek structures are envisaged by the author to have a deeper level, perhaps mantle origin.

The Slate Islands, McKellar Creek and Dead Horse Creek structures are the product of alkalic magmatic events. In the case of the Slate Islands, the magma is perhaps of diabasic composition, while that of McKellar and Dead Horse Creeks is carbonatite. Consequently, these structures and/or associated magmatism are likely to extend to considerable depths.

The diatremes were initially explosively emplaced followed by a period of fluidization during fluid dissipation. The best example of fluidization can be seen in a breccia dike on the north side of Spar Island, and in one of the larger breccia dikes on the east coast of Patterson Island of the Slate Islands group. Within these dikes, clasts are distinctly graded from fine to coarse from the dike wall to dike centre. Such gradation can be considered characteristic of laminar flow in a fluidized system (Bhattacharji 1967), and is unlikely to occur as a result of an instantaneous meteorite impact event as suggested by Halls and Grieve (1976). Within the mainland diatremes, clast size variation like that on Spar Island, Slate Islands, was not observed. The rounding of the Sibley clasts implies milling in a fluidized system, and not just a simple collapse after the initial explosion formed the diatreme. Rounded clasts are present in the Dead Horse Creek breccias, but they are not as prominent as the white to pinkish white Sibley clasts at McKellar Creek.

Woolsey *et al.* (1975) conducted experiments designed to duplicate structures found in diatreme intrusions. In brief, they concluded that:

1. Experimental results support gas-solid streaming for diatreme emplacement.
2. The upper portion of diatreme conduits are funnel shaped.
3. Convective particle circulation produced subsidence ring structures and caused descent of low strength blocks along pipe margins.
4. Surface doming with associated ring and radial fractures preceded eruption.
5. Maar-type craters developed following breakthrough and fluidized materials produced rings of air fall ejecta.
6. Prior to development of fluidization cells, intricate subsurface fracture patterns were observed propagating to surface.
7. Compressive deformation of adjacent strata occurred as a result of explosive eruption.

8. Shear fractures, cone shaped and inward-dipping, developed when a competent subsurface layer was fractured and lifted by gas pressure.

9. Accretionary lapilli and deeply subsided, nested saucer-shaped bedding were direct results of bedding fluidization.

10. Some annular segregation of particles by size was observed.

11. Subsequent diatreme activity may destroy early formed structures.

The experimental studies have subsequently documented all features found in diatreme intrusions that have been reported in the literature (Woolsey *et al.* 1975, McCallum *et al.* 1976). As for the structures found on the north shore of Lake Superior, evidence for items 1, 3 and 10 appears applicable to one or more of the structures, while the other items were not observed or could not be documented because of insufficient data.

The most significant observation is the occurrence of rocks, within the diatremes, younger than those presently enclosing the diatreme. A large block of amygdaloidal lava (Late Precambrian) occurs in a diatreme dike on the southeast corner of Patterson Island of the Slate Islands group, and Sibley fragments occur within the McKellar Creek structure. Rocks enclosing both of these diatreme structures are Early Precambrian in age. These are good examples of lithologic fragments of higher stratigraphic position collapsing downward during the diatreme emplacement process. Hearn (1968) and Snyder and Gerde-mann (1965) reported diatreme structures that contain lithologic blocks from a higher stratigraphic position, in one case on the order of 900 m higher.

Another interesting observation is that the diatremes need not have a recognizable igneous matrix. Harris *et al.* (1970) postulated that adiabatic expansion of volatiles, explosively released during diatreme emplacement, would cause the associated silicate melt to solidify. Therefore, at high levels within a diatreme structure, evidence of magma associated with diatreme development may be lacking (Harris *et al.* 1970).

Other investigators such as McGetchin *et al.* (1973) have concluded that the diatremes may be emplaced by a supercritical fluid containing solid rock fragments at subsolidus conditions with respect to silicate melts. In this model, an actual silicate magma need not have been present.

In the case of the north shore structures, the above models may account for the lack of igneous matrix in the Slate Island and McKellar Creek structures. The author considers the mica-bearing carbonate, which formed the major component in two or three outcrops at Dead Horse Creek, to be magmatic, and thus a carbonatitic origin is postulated for this breccia. With the exception of these two or three outcrops, a magmatic component to the Dead Horse Creek structure is not present. Coe (1966) has also postulated a carbonatitic origin for diatreme structures in Cork, Ireland, however, similarities between the diatreme at Cork and the north shore structures are unclear.

Table 13 compares field observations at the unmineralized Slate Islands diatremes with observations at the McKellar Creek and Dead Horse Creek diatremes. There are strong megascopic similarities between the mineralized and unmineralized structures. The difference between diatremes of economic interest and those of only academic interest appears to lie in the source of the fluids accompanying diatreme formation.

DIATREMES NORTH OF LAKE SUPERIOR

TABLE 13. COMPARISON OF THE UNMINERALIZED SLATE ISLANDS DIATREMES AND THE MINERALIZED MCKELLAR CREEK AND DEAD HORSE CREEK DIATREMES.

	Slate Islands	McKellar Creek	Dead Horse Creek
Lamellae in quartz grains	Yes	Yes	No
Shatter cone structures	Yes	No	No
Clast size zonation	Yes	No	No
Higher level lithologic fragments	Yes	Yes	No
Lower level lithologic fragments	No	No	No
Rounded clasts	Yes	Yes	Yes
Hydrothermal alteration	Yes	Yes	Yes
Hornfelsed and altered contacts	Yes	Yes	Yes
Sharp cross-cutting contacts	Yes	*	Yes
Local clast source	Yes	Yes	Yes
Evidence for multiple emplacement	No	No	No
Evidence for effusive products	No	No	No
Evidence for a discrete magmatic phase**	No	No	No

NOTES.

Yes — Observed.

No — Not observed (in this survey).

*Actual contact of breccia and wallrock not observed, however on the south flank, the breccia and altered wallrock outcrop very close (2 to 3 m). The spatial distribution implies the existence of a sharp contact.

**A breccia consisting of rounded Gunflint iron formation and diabase clasts in a diabase matrix occurs on the west coast of Patterson Island of the Slate Islands. It is uncertain what age this dike is. It appears to be the leading edge of a diabase intrusion following breccia emplacement.

KIMBERLITE-CARBONATITE-DIATREME RELATIONS

Carbonatite-kimberlite relations are at present controversial; however, the majority of workers appear to favor a relationship between these rock groupings, or at least a relationship between kimberlites and some carbonatites. A brief discussion of this relationship is warranted to bring to the attention of workers in the north shore area the potential for kimberlite intrusions and possibly the discovery of diamond. The region currently manifests all aspects of alkalic rock-carbonatite magmatism with the exception of kimberlite.

In recent times, Dawson (1966) has been the most outspoken advocate of a close connection between carbonatite and kimberlite rocks. This interrelationship is based on a number of observations which are as follows (Dawson 1966).

1. Kimberlite is commonly closely associated in space and time with carbonatites.
2. Kimberlites are separated from peridotites and serpentinites on the basis of chemistry. Kimberlites have high K_2O , TiO_2 , CaO , CO_2 , P_2O_5 , and H_2O contents; low SiO_2 ; high K/Na ratio; and low Mg/Fe ratio which sets them apart from peridotites and serpentinites.
3. Kimberlites have high concentrations of Li, Rb, Sr, Ba, Y, La, Zr, and Nb, similar to carbonatite and associated rocks.

Dawson (1966) concluded that the intimate spatial, temporal and chemical characteristics between kimberlite and carbonatite cannot be fortuitous. He attributed kimberlite to assimilation of crustal granite by a carbonatite magma: an assimilation model for kimberlite formation is not strongly supported at present, but a detailed discussion of this problem is beyond the scope of this report.

In 1967, Dawson added the following observations to his previous list supporting a possible carbonatite-kimberlite relationship.

1. Kimberlite and carbonatite are chemically gradational into each other.
2. In Russia the rare minerals moissanite and pyrochlore have been reported from both rock types.
3. Garnet peridotite nodules identical to those found in kimberlite have been found in carbonatite tuffs in Tanganyika.
4. The phenomenon of potassic metasomatism (finitization), a common feature at carbonatite contacts, has been recorded alongside a dike of diamond-bearing mica peridotite in the Ivory Coast.

In 1969, Janse completed a study of the Gros Brukkaros volcano, Southwest Africa, and concluded that the volcano represented the effusive product of a volatile-rich ultrabasic magma which displayed carbonatite-kimberlite relationships. Janse (1969) made the following observations:

1. High CaO , CO_2 , and Fe_2O_3 contents indicated a carbonatite of ankeritic character.
2. Relatively high Cr, Ni, and V contents characteristic of an ultrabasic suite, and high La, Li, Nb, Sr and Y indicating a kimberlitic character.
3. Relatively high Nb is characteristic of both kimberlitic and carbonatitic magmas.
4. Presence of aegirine and zoned biotite which are typical of carbonatites.
5. Pseudomorphs of olivine phenocrysts and perovskite which are possibly more related to kimberlite.

The model presented by Janse (1969) was that of a kimberlite magma with a carbonatitic top which explosively penetrated to surface upon reaching water-rich Nama sediments.

Mitchell (1970) reviewed the evidence for a carbonatite-kimberlite relationship, and concluded that kimberlite is not related to carbonatite, and that a kimberlite-basalt relationship is more likely.

In 1973, Dawson and Hawthorne investigated kimberlite sills at Benfontein, South Africa and made the following observations:

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1. Many layers within the sills displayed magmatic sedimentation and cumulus textures.
2. The transporting medium or intercumulus liquid was carbonate-rich, and on the basis of trace element chemistry, had carbonatitic affinities.
3. Calcite layers in the sills have diapirically penetrated the overlying layers in the sill.
4. The country rock shales have been thermally metamorphosed and the dike contains quench calcite and apatite.
5. Kimberlite apparently intruded as highly mobile fluid with megacrysts of olivine, garnet, pyroxene, mica, and picro-ilmenite in hot carbonatitic liquid.

This study established a close relationship between kimberlite and some forms of carbonatite magmatism.

McGetchin *et al.* (1973) completed a study of the Cane Valley diatreme, San Juan County, Utah, where carbonatitic dikes cut kimberlite dikes, which in turn cut diatreme breccia. McGetchin *et al.* (1973) visualized the diatreme as having been emplaced as a supercritical fluid entrained with rock fragments of mantle and crustal origin; the distinction between carbonatite and kimberlite phases may not exist at depth. These investigators picture the diatreme emplacement process as being from the mantle, and requiring 1 hour at a temperature of about 600°C.

Ferguson *et al.* (1975) completed an additional study of Gros Brukkaros, and confirmed the earlier work by Janse (1969), which established a carbonatite-kimberlite relationship. Chemical and phase equilibria studies of the volcano support a model of kimberlite, melilitite- and monticellite-bearing alkaline rock, and carbonatite from a common parent. This study convinced the investigators that carbonatite was an immiscible phase of alkaline magmatism formed at the top of a kimberlite magma, which was explosively emplaced upon breaching of the roof rocks (Ferguson *et al.* 1975).

In the model of Ferguson *et al.* (1975), the carbonatite represents an immiscible phase of ultramafic alkaline magmatism. They believe that both kimberlite and alkaline ultramafic magma can be produced by the same parent, if olivine fractionation is followed by reaction of olivine with carbonate-rich kimberlitic magma to produce melilitite (Ferguson *et al.* 1975). These investigators visualized a kimberlite magma as having been generated at depths in excess of 100 km by a small degree of partial melting of four-phase garnet ilherzolite. In the model of Ferguson *et al.* (1975), the explosive breaching of roof rocks would be expected to produce diatreme structures.

Le Bas (1977) has concluded that there are two types of carbonatite: the carbonatite-kimberlite association and the carbonatite-kimberlite-nephelinite association. The distinction between these two types is that the latter is the result of differentiation from a Ca-Na-K-rich magma, while the former is not. Loubet *et al.* (1972) had earlier subdivided carbonatite and kimberlite magmas, concluding that kimberlites result from reducing conditions and carbonatites from oxidizing conditions.

Mitchell (1979) reviewed the kimberlite-carbonatite relationship for the second time, and made the following points, in discounting a carbonatite-kimberlite relationship.

1. The carbonate-rich residue of kimberlites is not the same as that of carbonatites. The mineralogy of the kimberlite residuum is rich in primary serpentine and calcite, exhibits liquid immiscibility features, lacks Na-Fe silicates and Nb minerals. Spinel (magnetite) are rare in kimberlite residuum, but common in carbonatite.
2. Lamprophyres, previously classified as central complex kimberlites from the Fen alkaline complex (Norway) and Ile Bizard diatreme (Quebec) differ from true kimberlites in mineralogy. Kimberlites contain magnesian ilmenite, pyrope garnet, titaniferous-magnesian-aluminous chromite, magnesian ulvospinel, ulvospinel-magnetite solid solutions and rare Al_2O_3 -poor pyroxenes. Lamprophyres contain andradite-grossular garnet, manganoan ilmenites, titaniferous-aluminous-magnesian chromites, ulvospinel-magnetites, Al_2O_3 -rich pyroxenes, nepheline and melilitite.
3. Kimberlites, carbonatites and alkaline rocks are enriched with incompatible trace elements, however, similar trace element content does not imply a genetic relation-

ship. Partial fusion, fractional crystallization, volatile enrichment, acting independantly or together on unrelated magmas may produce similar incompatible trace element contents.

4. Kimberlites are not associated with rift tectonics which characterizes carbonatite magmatism. Kimberlites cluster in interrft zones.

Within the framework of the present project, kimberlites were not encountered. Within Ontario, only a few scattered occurrences of kimberlite or possible kimberlite have been described, and these are dike-like bodies. The best known occurrence is the kimberlite dike in the Upper Canada mine, Kirkland Lake area (Lee and Lawerence 1968). This dike is 1 m wide, strikes 340 degrees, and has a vertical dip (Lee and Lawerence 1968).

Alkalic rock-carbonatite magmatism within Ontario has been controlled principally by three structures: the Ottawa-Bonnechere graben system (Kumarapeli and Saull 1966); the Kapuskasing horst structure (Bennett *et al.* 1967); and the Big Bay - Ashburton Bay fault zone (Sage 1978). These three structures have at least one common denominator in that they tap the upper mantle, and they have controlled siting of alkalic rock-carbonatite magmatism. Mitchell (1979) claimed there is no close association of kimberlite intrusion and rifting, however, Dawson (1970) reported that at least some kimberlites occur in rift structures. The kimberlite dike in the Upper Canada mine (Lee and Lawerence 1968), may have been emplaced in an extension of the Lake Timiskaming branch of the Ottawa-Bonnechere graben system.

While the kimberlite-carbonatite-diatreme association cannot be unequivocally established in Ontario, there is sufficent evidence in other parts of the world to imply that structures controlling alkalic rock-carbonatite intrusion may also control kimberlite and/or diatreme emplacement.

DIATREMES AND KIMBERLITES

In addition to the previously mentioned carbonatite-kimberlite affinities of the Cane Valley diatreme (McGetchin *et al.* 1973), the Sloan kimberlite has been described as a diatreme (McCallum and Egger 1971). This kimberlite-diatreme contains carbonate, which in the opinion of McCallum and Egger (1971) was a carbonatitic liquid associated with the kimberlite.

Clement (1975) proposed that kimberlite breccias in some South African pipes are the result of liquid immiscibility in a mixture of K-rich silicate liquid and carbonatitic liquid in association with a gas phase. Upon reaching a certain level in the crust, the internal gas pressure exceeds lithostatic pressure and explosively breaches the cap rocks (diatreme). The associated magma and cap rocks are then fluidized by the low density, low viscosity carbonatitic magma (Clement 1975). This model was also used to explain blocks of high level cap rock found deep within the diatreme structure: these resulted from settling in a low density (carbonatitic) fluid, and from collapse of the wall rocks following pressure release at the time of explosion (Clement 1975). Clement thus tied kimberlites, carbonatites, and diatremes into a single event.

McCallum *et al.* (1975) reported 36 kimberlitic diatremes in Colorado and Wyoming, and a year later, McCallum (1976) reported on serpentinized, fenitized and carbonated nodules found within the Sloan diatreme. The recognition of fenitization in a kimberlitic diatreme makes a connection with carbonatites which are customarily enveloped in a fenitic halo.

Hearne (1968) described diatremes with kimberlitic affinities in north-central Montana, and Hawthorne (1975) proposed a diatreme model for various diatreme pipes in Africa. Diatremes containing kimberlite with diamonds have been described by Davidson (1964), Trofimov (1971) and Gogiheni *et al.* (1978).

In summary, it is reasonable to conclude that these three rock classes may be related. The carbonate associated with kimberlite may be the remains of the fluidized system accompanying the emplacement of kimberlite, which existed at temperatures below the silicate solidus. The kimberlite-carbonatite rocks are likely the result of very low degrees of partial melting, while the carbonatite-nephelinite association represents higher degrees of partial melting followed by liquid immiscibility, crystal fractionation, and alkali-volatile loss. Thus carbonatite-kimberlite relationships possibly reflect differing degrees of partial melting and magmatic evolution of the melts rather than any major difference in the source area or the means of formation.

In the Lake Superior region, diatremes and carbonatites are now known to exist. Therefore, the possible existence of kimberlitic rocks in this region should not be overlooked. Subsequent to completion of mapping of the north shore diatremes reported here, Cannon and Mudrey (1980) have reported the presence of post Ordovician kimberlite in Iron County, Michigan, which lies on the extrapolated extension of the Big Bay - Ashburton Bay fault.

URANIUM MINERALIZATION IN DIATREME STRUCTURES

Within Canada, the recognition of uranium mineralization in diatreme structures is a relatively new development. The earliest account of uranium in breccia of possible diatreme origin, of which the author is aware, is that of Reinhardt (1972), who described the uranium-mineralized exotic breccias from the Great Slave Lake area of the Northwest Territories.

In recent years, several occurrences of uranium-bearing intrusive breccias have been described from the Yukon by Bell (1978), Bell and Delaney (1977), and Archer and Schmidt (1978). Bell described the breccias as being mineralized with uraninite and brannerite. The breccias also contain anomalously high quantities of Ti, Co, Ni, Fe, K, Ba, Cu, U, and rare earths, most of which are also anomalous in the McKellar Creek and Dead Horse Creek breccias. The rocks were affected by alkali, carbonate, silica, and iron metasomatism (Bell 1978, p.317; Bell and Jones 1979, p.398), which is also typical of the metasomatic alteration found within the McKellar Creek and Dead Horse Creek breccias. Bell (1978) considered the breccias to be fault controlled, and to consist of shatter columns produced by hydraulic fracturing accompanied by fluids leaching Fe, Cu, and U from associated black shale rocks and causing bleaching. The metals were transported higher up to their site of deposition (Bell 1978). Black shale rocks which could supply such metals in Bells (1978) model, are not known to occur within the area of diatreme emplacement north of Lake Superior. Bell (1978, p.319-320) considered the breccia forming event to be explosive, followed by fluidized emplacement with limited vertical movement of fragments. The breccias consist of rounded altered and unaltered fragments with accompanying siderite and magnetite, and with associated barite and magnetite veins (Bell 1978). The main difference between the observations of Bell (1978) and the author concern evidence for considerable vertical movement (McKellar Creek) which is in contrast to minor or little vertical movement in the Yukon breccias. Also, the invoking of wall rock source beds for the metals found in the Yukon structures by Bell (1978) contrasts with the authors model of mantle origin in association with a carbonatite magma. Wall rock sources for the mineralization found at McKellar Creek and Dead Horse Creek do not appear likely.

In the Baker Lake area, Miller (1979) reported on a copper-uranium bearing diatreme structure cutting gneissic rocks. The breccias have a groundmass that is oxidized, chloritized, and carbonatized (Miller 1979). The breccia is cut by and closely associated with stocks and dikes of porphyritic to glomeroporphyritic biotite trachyte and is therefore related to alkaline magmatic process (Miller 1979). An association with trachyte was not observed for the McKellar and Dead Horse Creek structures, even though several small trachyte dikes cut the Dead Horse breccias. These trachyte dikes are common within the Port Coldwell alkalic intrusion, and where found, they always cause a response on a spectrometer and contain detectable uranium and thorium. Diatremes are not associated with the trachyte dikes found within the Port Coldwell complex. The abundance of carbonate, and the minor element chemistry suggests a carbonatitic rather than trachytic parent for the McKellar Creek and Dead Horse Creek breccias. Miller (1979) described the matrix of the Baker Lake diatreme structure as carbonate, rock flour, and aphanitic trachyte. Miller (1979) reported the following minerals within the breccias: pitchblende, chalcopryrite, sphalerite, pyrite, calcite, dolomite, barite, quartz, and hematite. The mineralization is restricted to the diatreme structure (Miller 1979) as is also the case with the north shore diatremes. Other diatreme structures, apparently unmineralized, occur in the same region (Miller 1979).

Uranium mineralization in association with diatreme structures is well documented in the southwestern United States. These structures are Pliocene in age (Shoemaker 1956), much younger than the ones examined by the author, however, they have similar minor element chemistry. Shoemaker (1956) studied uranium-bearing diatremes on the Navajo and Hopi reservations in Arizona, New Mexico, and Utah, and made the following observations.

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1. Some diatremes contain phlogopite-bearing serpentine typical of kimberlite.
2. Volcanic and associated rocks are alkalic basalt, which, in the intrusive phase, would be lamprophyre, monchiquite, and minette.
3. Alkalic rocks (monchiquite) have high Ti, P, Zr, Ba, Nb, H₂O and Ce-group rare earth elements.
4. Minettes have high concentrations of P, Ba, Sr, Be, B, Pb, and H₂O and Ce-group rare earth elements.
5. Both monchiquite and minette are anomalously high in radioactivity, principally thorium.
6. Highest uranium values occur in laminated siltstone and shale, overlying sedimentary unconformities within the diatreme, and deposition is likely influenced by rock permeability.
7. The source of uranium was hydrous phosphate-rich monchiquite magmas.
8. In vertical section, the upper part of the diatreme vent is filled with bedded tuff, limestone, clay, siltstone, and chert. Lower down, below the tuff, breccia agglomerate, and ultimately igneous rock are present. The McKellar Creek and Dead Horse Creek structures would be exposed at the intermediate level of this model.
9. Blocks of wall rock greater than 3 m across have been displaced downward up to 600 m.
10. Explosions may have been multiple, as angular blocks of stratified tuff are incorporated in later tuff. Bedded tuffs are not present in the north shore diatremes.
11. Uranium associated with limestone may be syngenetic with the limestone. The carbonate is high in phosphate and contains unusually high amounts of Sr, V, Co, and Cu. The minor element chemistry of the structures studied by Shoemaker (1956) is similar to that of the Dead Horse Creek and McKellar Creek structures. On the basis of Shoemaker's (1956) model of vertical stratigraphy, both the McKellar and Dead Horse structures are exposed in their intermediate to lower portions, and the Dead Horse Creek diatreme may reflect lower stratigraphy than the McKellar Creek diatreme.

In 1962, Shoemaker *et al.* described in detail the uranium deposits in diatremes at Hopi Buttes, Arizona. Observations by these investigators are summarized below.

1. Uranium is restricted to diatremes with bedded carbonate rocks. It locally occurs in fine-grained nonvolcanic clastic rocks, in tuffs, and in sedimentary wall rock fragments.
2. The uranium content is a few thousandths of a percent in carbonate rocks which contains variable Ca, Mg, clastic quartz and volcanic debris.
3. Carbonate is enriched in Na, Sr, V, Cu, Ni, Co, U, and Mo. Rocks contain, on an average, five times more phosphorus than normal limestone and significantly more As and Se. Mo was the only element correlatable with uranium.
4. The carbonate in the diatremes was formed from evaporation of thermal springs. The unusual element concentrations found in limestone are also present within monchiquite and limburgite dike rocks. Fossils have been identified in some limestone. A genetic link between solutions and igneous rocks is likely.
5. Highest concentration of uranium is found mainly in fine grained clastic sedimentary rocks and lapilli tuff in three structural settings:
 - A. at the conformities within the diatreme;
 - B. at the vent walls of the diatreme; and
 - C. enclosing beds of coarse breccia.

6. Uranium in diatremes may be syngenetic with diatreme formation, however, local enrichment occurs in clastic rocks where distribution is structurally controlled.

On the basis of chemistry, the Hopi Buttes deposits appear to have some similarity to those found near the northeast corner of Lake Superior. On the basis of spectrometer readings, the enrichment of uranium towards the flanks of the Hopi Buttes diatreme appears to be similar to the distribution at Dead Horse Creek. While Shoemaker *et al.* (1962) described the carbonates in terms of sediments and spring deposits, the chemistry is in some

respects typical of carbonatites and generally similar in chemistry to carbonate at Dead Horse Creek.

In 1963, Malde and Thaden described diatreme structures in the Monument Valley area of Arizona. In these structures, blocks of cap rock have subsided 380 m and basement rocks have moved up 1200 m. Minor uranium mineralization is reported by them to occur along the flanks of the intrusion.

Gabelman (1977) presented a model for uranium mineralization which appears to be applicable to the McKellar and Dead Horse Creek structures. A summary of some of his main points are as follows:

1. Mantle degassing is a principal means of radioactive element transfer. A differentiation product consisting of concentrated volatiles and fluid without magma may contain more radioactive elements than alkalic rocks and carbonatites. These volatiles may be the diatreme drilling agent.
2. Diatremes feeding mantle volatiles at tectonically weak foci may be an important factor in forming districts containing productive uranium deposits.
3. Uranium is present at higher than trace levels within most thorium-fluorite-magnetite or carbonatite pipes and in alkalic complexes. Uranium deposits are known in many areas surrounding these alkalic complexes.
4. Many igneous breccias are mineralized with copper and uranium, and many uranium districts contain such pipes, whether mineralized or not.
5. Radiation patterns over diatremes are generally a central low with scattered small sharp anomalies, enclosed in a marginal high extending out, and fading into the country rock to regional background.
6. The Orphan mine, Grand Canyon, Arizona, contained a marginal ring of rich ore within the pipe against its boundary with the wall rocks. Ore was also found extending as masses, pods, and stringers up to 3 km from the contact along favorable stratigraphic horizons.

On the basis of minor element chemistry and alteration, the author has interpreted the McKellar Creek and Dead Horse Creek structures as having carbonatitic affinity, implying a mantle source for the mineralization. The author would thus concur with the Gabelman (1977) concept of diatreme feeding of mantle volatiles for the McKellar and Dead Horse structures. The distribution of radioactivity at the Dead Horse Creek structure is apparently similar to that noted by Gabelman (1977). The author would not anticipate any large scale migration of the mineralization beyond the confines of the diatreme structures, since the enclosing schistose metavolcanics and metasediments lack the porosity and permeability to permit access of the mineralizing fluids. The mineralized shear zone along the south flank of the West Dead Horse subcomplex permitted access of these fluids. The lack of permeability in the surrounding rocks prevented dilution or dissipation of the fluids, and likely accounts for the intensity of mineralization in this zone.

While Gabelman (1977) considered the Orphan mine to be the result of diatreme activity, Gornitz and Kerr (1970) considered it to be the result of solution collapse of limestone. Such a solution-collapse model is not applicable to the north shore structures because of the lack of carbonate rocks.

Kerr *et al.* (1957) described uranium-bearing collapse features in the Temple Mountain area, Utah, which may also be diatreme structures.

RECOMMENDATIONS FOR REGIONAL EXPLORATION

On the basis of regional geology, the author has indicated three possible areas for the location of additional diatreme structures north of Lake Superior (Figure 14). Success in these areas would suggest that a number of other prominent linear structures north of Lake Superior may warrant re-evaluation for uranium-thorium mineralization.

Uranium-thorium in the diatremes is likely of mantle origin, related to carbonatite magmatism, as suggested in a model proposed by Gabelman (1977), and thus the rocks bordering the diatreme structure have no bearing on whether uranium mineralization is present or absent. Breccias that have undergone the greatest alteration and replacement offer the greatest potential for uranium-thorium mineralization. Within recent years, diatremes with kimberlitic affinities have been reported (Hearne 1968; McCallum *et al.* 1976) and kimberlite may be related to some varieties of carbonatites (McGetchin *et al.* 1973; Dawson and Hawthorne 1973). As a consequence of this inter-relationship, prospectors working within the region should be on the lookout for kimberlitic rocks.

The author considers that the mineralized breccias at McKellar Creek and Dead Horse Creek are coeval structures, which on the basis of field geology are Late Precambrian in age. Prospecting of diatremes should not be categorically restricted to this age group. The Dead Horse Creek structure displays strong carbonatitic affinities, and on the basis of rock alteration, the McKellar Creek structure is likely to have a similar genesis. The Slate Islands diatremes may have originated from a magma of gabbroic (diabasic) rather than carbonatitic origin. This study suggests that all diatremes are not equivalent in genesis, and that the origin of any particular structure can be determined only on the basis of field data. The middle Paleozoic isotopic age of the Slate Island lamprophyre dike with carbonatite affinities indicates that volatile rich magmatism, much younger than the Dead Horse Creek structure, existed along the Big Bay - Ashburton Bay structure, and therefore, under suitable conditions uranium-thorium mineralization of Paleozoic age could occur.

Uranium-thorium mineralization found within the diatremes examined may represent the terminal phase of an evolving alkalic petrogenetic cycle related to structures intimately involved with the development of the Lake Superior basin. Uranium mineralization exists in other areas bordering the Lake Superior basin (Nuffield 1956; Carter 1977). If this mineralization proves to be similar in age, then perhaps a metallogenic epoch can be identified for the region, and its relationship to the evolving basin established.

Field observations indicate that, as far as the diatremes north of Lake Superior are concerned, three items appear to be associated with the uranium-thorium mineralization. These are: 1) explosive release of volatiles to generate the breccia, i.e. plumbing system; 2) hydrothermal fluids containing the uranium-thorium plus iron and silica; and 3) a mantle derived carbonatitic source. The hydrothermal fluid may have originally been a fenitizing fluid which leached silica and iron(?) more proximally to an intruding carbonatite magma, and this modified fluid subsequently deposited the silica and iron along with uranium and thorium in a distal setting.

Control for the release of volatiles for diatreme formation are faults and shear zones related to the northern extension of the Big Bay - Ashburton Bay fault zone.

Figure 14 indicates possible favorable areas for diatreme structures. Prospectors working in this region should keep in close touch with developments in Michigan and Wisconsin, along the southwestern extension of the Big Bay - Ashburton Bay fault zone trend. As work along this southern portion (Klasner and Turner 1973; Klasner *et al.* 1975) continues, it is possible that new findings will modify or enhance the potential economic importance of this structure within Ontario. Recent work in northern Michigan by Cannon and Mudrey (1980) has identified the presence of kimberlite along the southwestern extension of the Big Bay - Ashburton Bay fault zone; such discovery enhances the possibility of similar rocks being present in Ontario along this same structure.

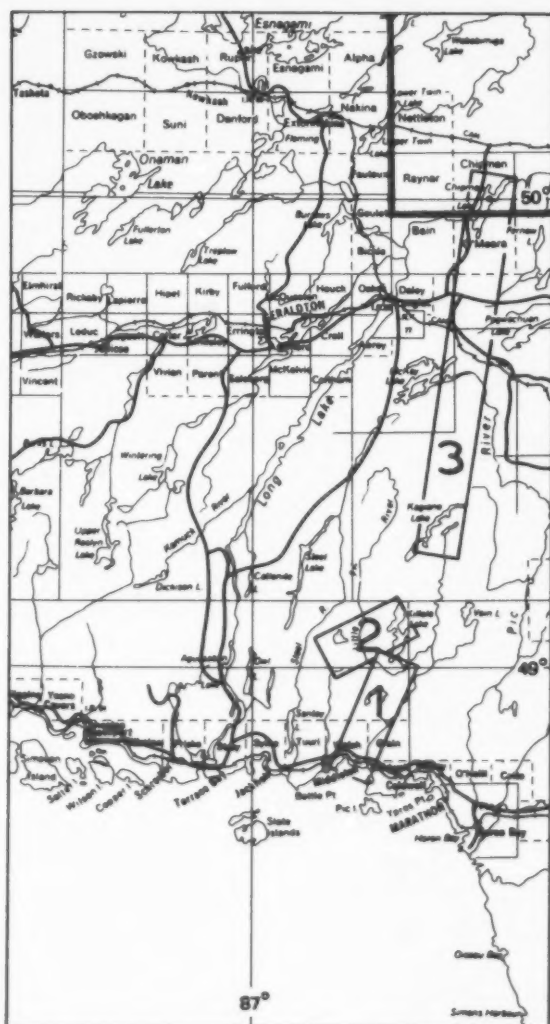


Figure 14. Areas recommended for prospecting for diatreme structures. Areas are numbered in order of decreasing priority. Scale 1:1,584,000.

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Spectrometer readings	33	Trachytic dike	15
Magma		Nephelinite	62
Alkalic carbonatite	61-63	Neys Diatreme	57, 58
Dead Horse Creek Diatreme	35, 40, 43,	Chemical analyses	17
47, 52, 54, 68		Geology	10-18
McKellar Creek Diatreme	34, 54	Origin	16, 18
Alkalic gabbroic		Photos	12, 13, 16
Neys Diatreme	15, 18	Niobium	33, 35, 52
Slate Islands Diatremes	21-22, 68	North Dead Horse subcomplex	39, 40, 44
Lamprophyre		Orphan mine	67
Gold Range Diatreme	5	Orthopyroxene	
Potassic granitic		Mafic hornfels	14
Granitic aplite dikes	36	Osler Formation	19
Magnetite		Ottawa-Bonnechere graben system	63
Carbonate-rich lamprophyre	45	Patterson Island	19-24 passim, 58, 59
Diabase	37	Perthite	
Mafic hornfels	15	Quartz-bearing microsyenite dike	15, 16
Olivine monzogabbro	14	Phenacite	52
Pyroxene syenite	14	Phosphate	33, 66
Matrix		Pic Island intrusive subcentre	10, 16
Breccia	15, 28-29	Pillow lava	36
Chemical analyses	17	Pitchblende	65
Melilite	62	Plagioclase	
Metasediments	25, 27, 36	Diabase	44
Chemical analyses	Chart B	Olivine monzogabbro	13
Clast		Quartz monzonite	38
Diatreme breccia	27, 35	Quartzite	28
Photos	26, 34, 41, 42	Trondhjemite	28
Spectrometer readings	33, 53, 54	Planar Structures	
Metavolcanics		Quartz	29-31
Felsic		Photo	29
Chemical analyses	Chart B	Port Coldwell alkalic complex	
Intermediate to felsic	5	 10, 18, 35, 38, 43, 45, 46, 56, 57, 65	
Spectrometer readings	9	Prairie Lake carbonatite	50, 52, 56, 57
Mafic	5	Pyrite	
Chemical analyses	Chart B	Breccia, explosion	5
Spectrometer readings	9	Carbonate-rich lamprophyre	45
Mafic to intermediate	35-36	Diatreme breccia	7, 15, 18
Spectrometer readings	53	Ironstone	5
Spectrometer readings	23	Pyrochlore	52
Mica		Pyroxene	
Carbonate-rich lamprophyre	45	Porphyritic: lamprophyre	46
Lamprophyre	7	Pyrrhotite	
Michipicoten Island fault	8, 56, 57	Breccia, diatreme	15, 18
Milling			
Breccia, diatreme	10, 27, 28, 29, 41, 58		

DIATREMES NORTH OF LAKE SUPERIOR

Quartz		South Dead Horse subcomplex	
Breccia matrix	29	35,38-43 passim, 50,51,54,55	
Deformation lamellae	29-31	Spar Island	19,58
Crystallographic angles	30	Spectrometer Readings	
Photo	29	Dead Horse Creek Diatreme	53
Quartzite	28	Gold Range Diatreme	9
Quartz Monzonite	5,7,37-38	McKellar Creek Diatreme	33
Spectrometer readings	9	Slate Islands Diatremes	23
Quartzite		West Dead Horse Subcomplex	54
Clast		Sulphides	
Diatreme breccia	27,28	Scapolite breccia	43
Photo	26	see also: Pyrite; Pyrrhotite	
Radioactivity		Syenite	10
Dead Horse Creek Diatreme	35,49, Chart B	Chemical analyses	Chart B
Carbonate-rich breccia	39	Photo	12
Diatremes	67	Spectrometer readings	53
McKellar Creek Diatreme	25,31,32, Chart B	Trachytic	10
see also: Spectrometer readings		Syenite aplite dikes	35
Rare earths	33	Syenite, biotite	44-45
Dead Horse Creek Diatreme	49, Chart B	Syenite clasts	
McKellar Creek Diatreme	32, Chart B	Diatreme breccia	
Red Sucker Cove	45	Alkalic feldspar	14
Regolith		Nepheline	14
See: Breccia regolith		Syenite, micro-	10
Rove Formation	27	Quartz-bearing dike	15-16
Scapolite		Chemical analyses	17
Breccia	35,40-43	Photo	16
Photos	41,42	Syenite, pyroxene	14
Schist		Terrace Bay	19
Quartz-biotite-plagioclase	25	Thorium	
Sericite		Biotite syenite	45
Chemical analyses	Chart B	Biotite trachyte	65
Schlieren	10	Dead Horse Creek Diatreme	51-52,55
Schreiber	4	Diatreme	68
Sericite schist		McKellar Creek Diatreme	31
Chemical analyses	Chart B	Trachytoidal texture	10,18
Shale, black	65	Trondhjemite	
Shatter columns	65	Amphibole-biotite	38
Shatter cones		Biotite dikes	36
Slate Islands Diatremes	19	Clast	
Shear zone	52,55,67,68	Diatreme breccia	27-28
Spectrometer readings	54	Spectrometer readings	53
Shock metamorphism		Tuff, laminated	36
Slate Islands Diatremes	19	Spectrometer readings	53
Sibley Group	27,28,29,34,58,59	Upper Canada mine	63
Photos	26,29	Uraninite	65
Spectrometer readings	33	Uranium	
Silica		Biotite syenite	45
Breccia, diatreme	46-47	Dead Horse Creek Diatreme	51-52,55
Siltstone	36	Diatreme	65-67,68
Slate	27	McKellar Creek Diatreme	31
Slate Islands	56	Syenite aplite dikes	35
Slate Islands Diatremes		Volatiles	5,18,47,58,67,68
30,31,47,57,58,59,60,68			
Chemical analyses	22, 50, Chart B		
Geology	19-24		
Spectrometer readings	23		
Soldi carbonatite intrusion	47		

Wall rock		West Dead Horse subcomplex	38,50
Dead Horse Creek Diatreme		Chemical analyses	Chart B
Chemical analyses	48-50, Chart B	Spectrometer readings	54
McKellar Creek Diatreme		Uranium-thorium	51-52,55,67
Chemical analyses	32,50, Chart B		
Slate Islands Diatremes		Xenoliths	
Chemical analyses	22,50, Chart B	Lamprophyre	7
Spectrometer readings	23	Quartz-bearing microsyenite dike	15
Weathering			
Breccia	39,41	Zirconium	52-55
Photos	34, 40, 42	Zonation	
		Diatreme clasts	19-20
		Amphibole	43,46

SYMBOLS

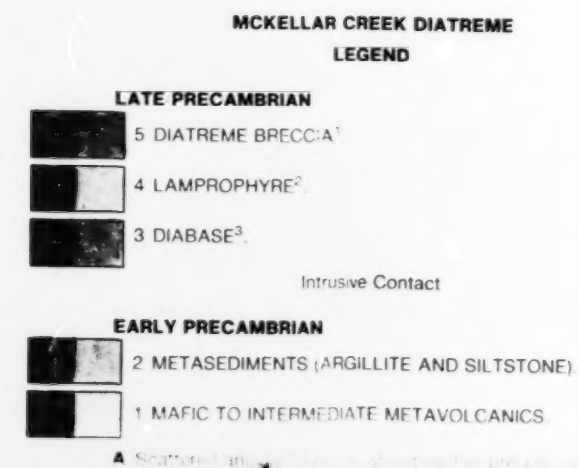
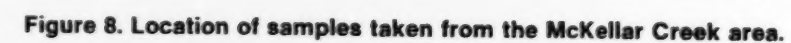
	Glacial striae, with direction of ice movement
	Geological contact, inferred
	Area of bedrock outcrop
	Area of weathered bedrock
	Small bedrock outcrop
	Bedding, inclined, vertical, tops unknown
	Bedding, inclined, vertical, tops known
	Schistosity, inclined, vertical
	Gneissosity, inclined, vertical
	Pillow elongation, inclined, vertical, tops unknown
	Small drag fold, with direction of plunge
	Fault, with movement indicated
	Lineation, q = quartz rodding, b = elongated biotite clots
	Top determination from grain gradation, overturned
	Shear zone, inclined
	Lineament, likely fault
RA	Radioactivity
MA	Magnetic attraction
	Logging skid road
	Intermittent stream
MC 76	Samples from McKellar Creek area
DH 25	Samples from Dead Horse Creek area
P 2	Location of photograph
	Swamp



Figure 8. Location of samples taken from the McKellar Creek area.

MCKELLAR CREEK DIATREME LEGEND

LATE PRECAMBRIAN	
	5 DIATREME BRECCIA ¹
	4 LAMPROPHYRE ²
	3 DIABASE ³
Intrusive Contact	
EARLY PRECAMBRIAN	
	2 METASEDIMENTS (ARGILLITE AND SILTSTONE)
	1 MAFIC TO INTERMEDIATE METAVOLCANICS



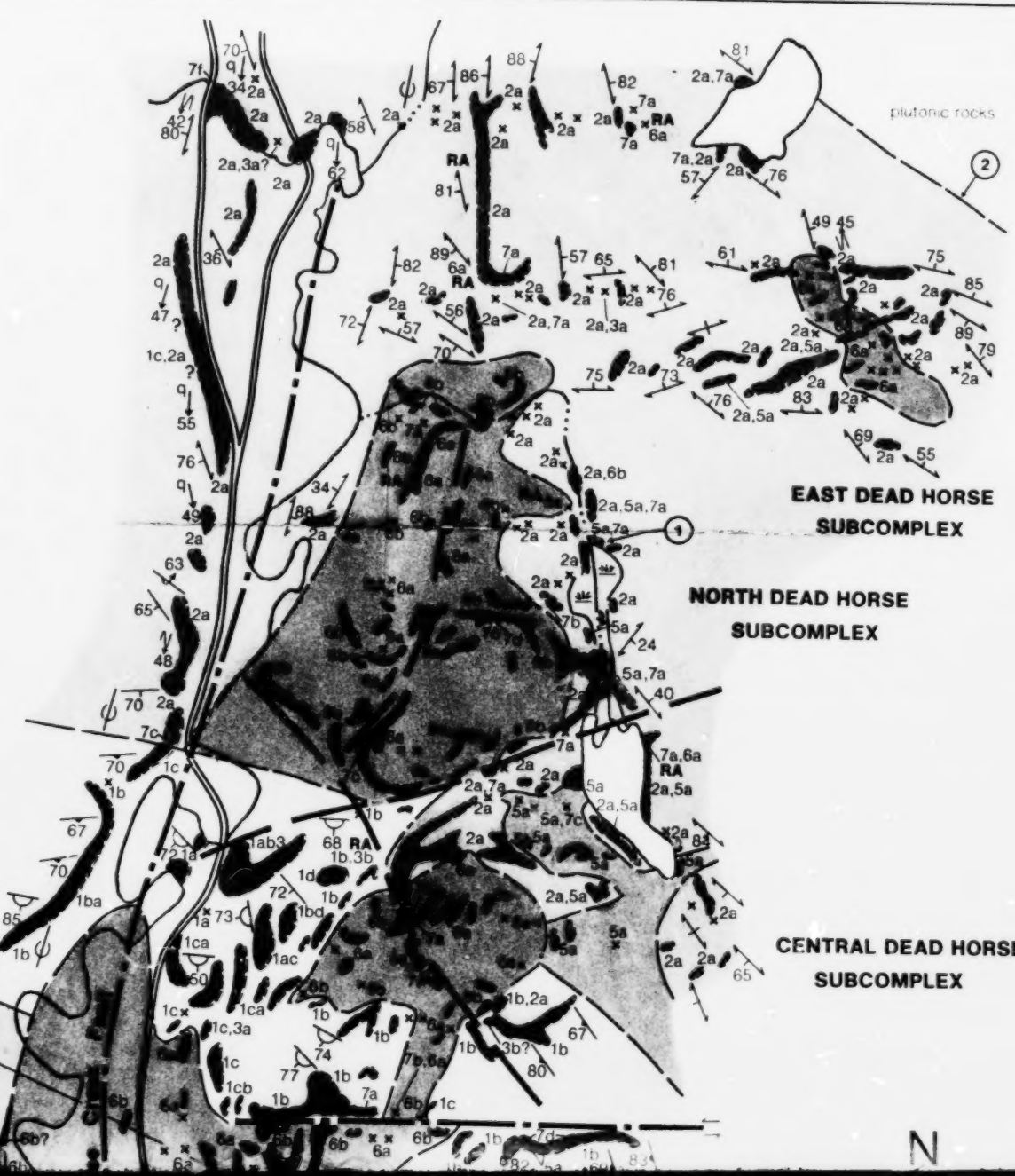
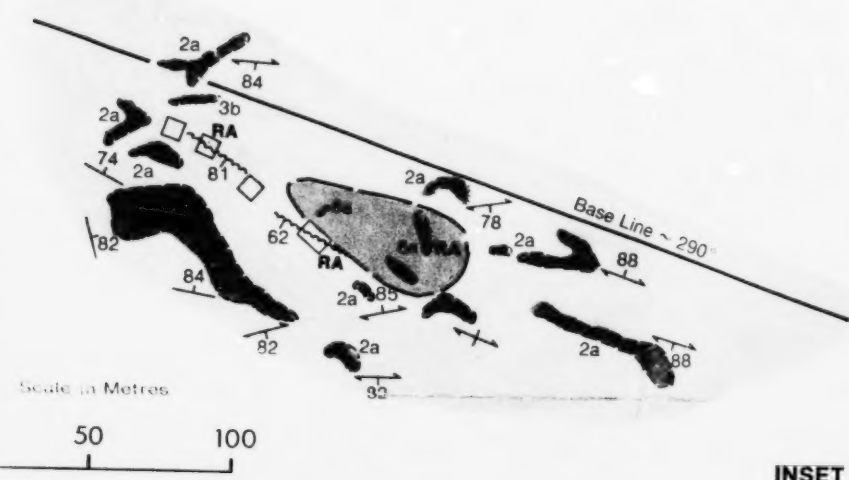
- P2 1: aerial photograph
- Swamp
- Pit
- Diamond drill hole



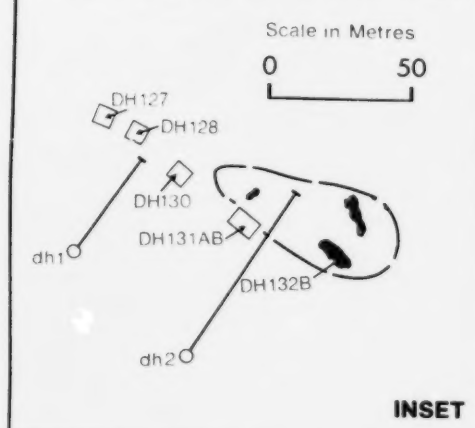
- EARLY PRECAMBRIAN**
- 2 METASEDIMENTS (ARGILLITE AND SILTSTONE)
 - 1 MAFIC TO INTERMEDIATE METAVOLCANICS
- A** Scattered angular boulders of radioactive breccia, source unknown.
- B** Large fragments of Sibley Formation(?)
- Notes:**
1. Age relations of breccia to diabase and lamprophyre are uncertain.
 2. Age relations of lamprophyre to diabase and breccia are unknown.
 3. Age relation of diabase to lamprophyre and breccia is unknown.

Figure 7. Geology of the McKellar Creek diatreme. Geology by R.P. Sage.

WEST DEAD HORSE SUBCOMPLEX



WEST DEAD HORSE SUBCOMPLEX



DEAD HORSE CREEK DIATREME

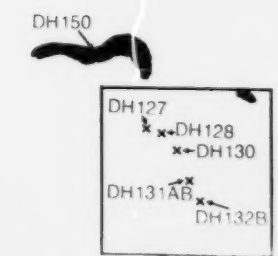
LEGEND

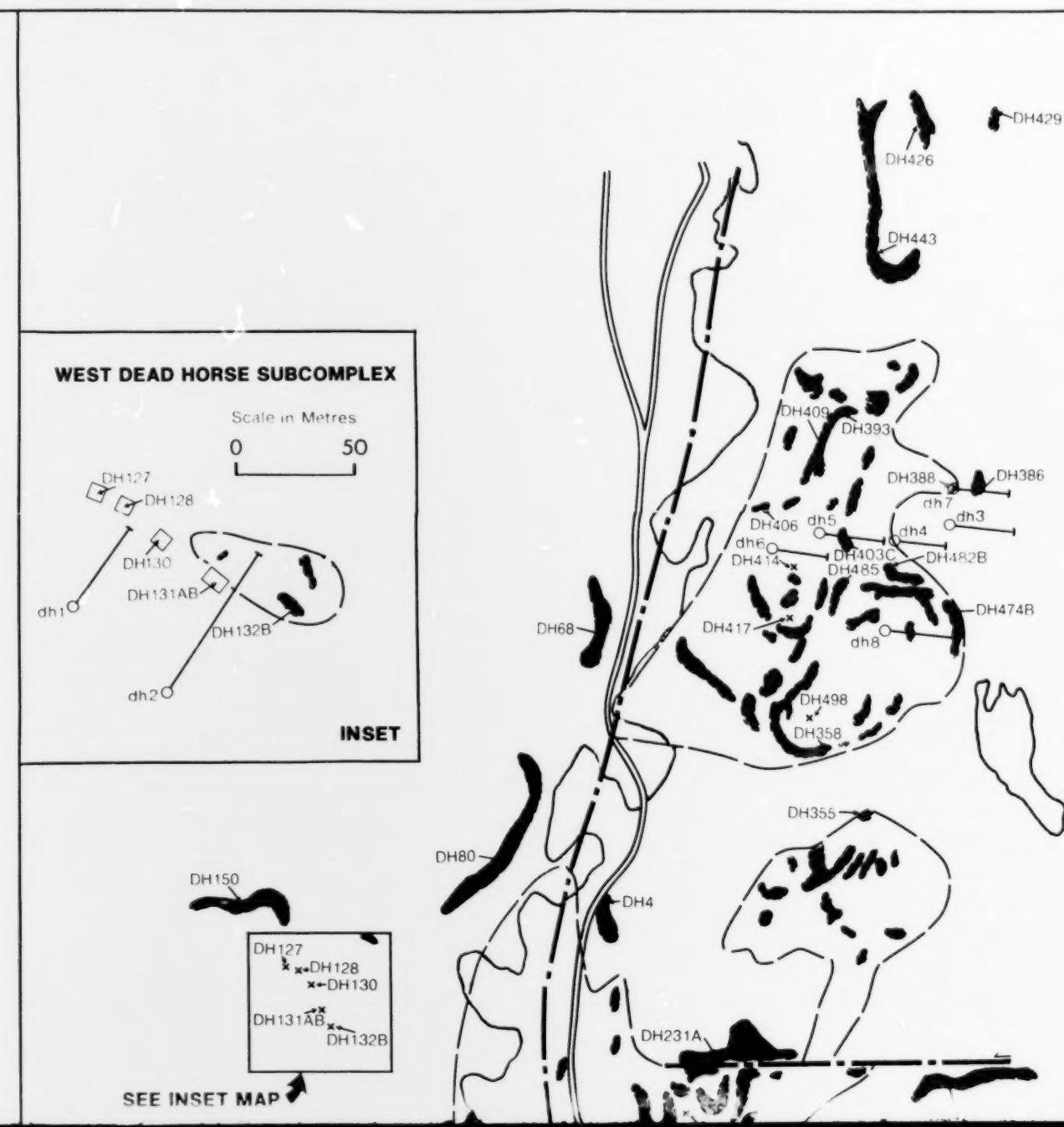
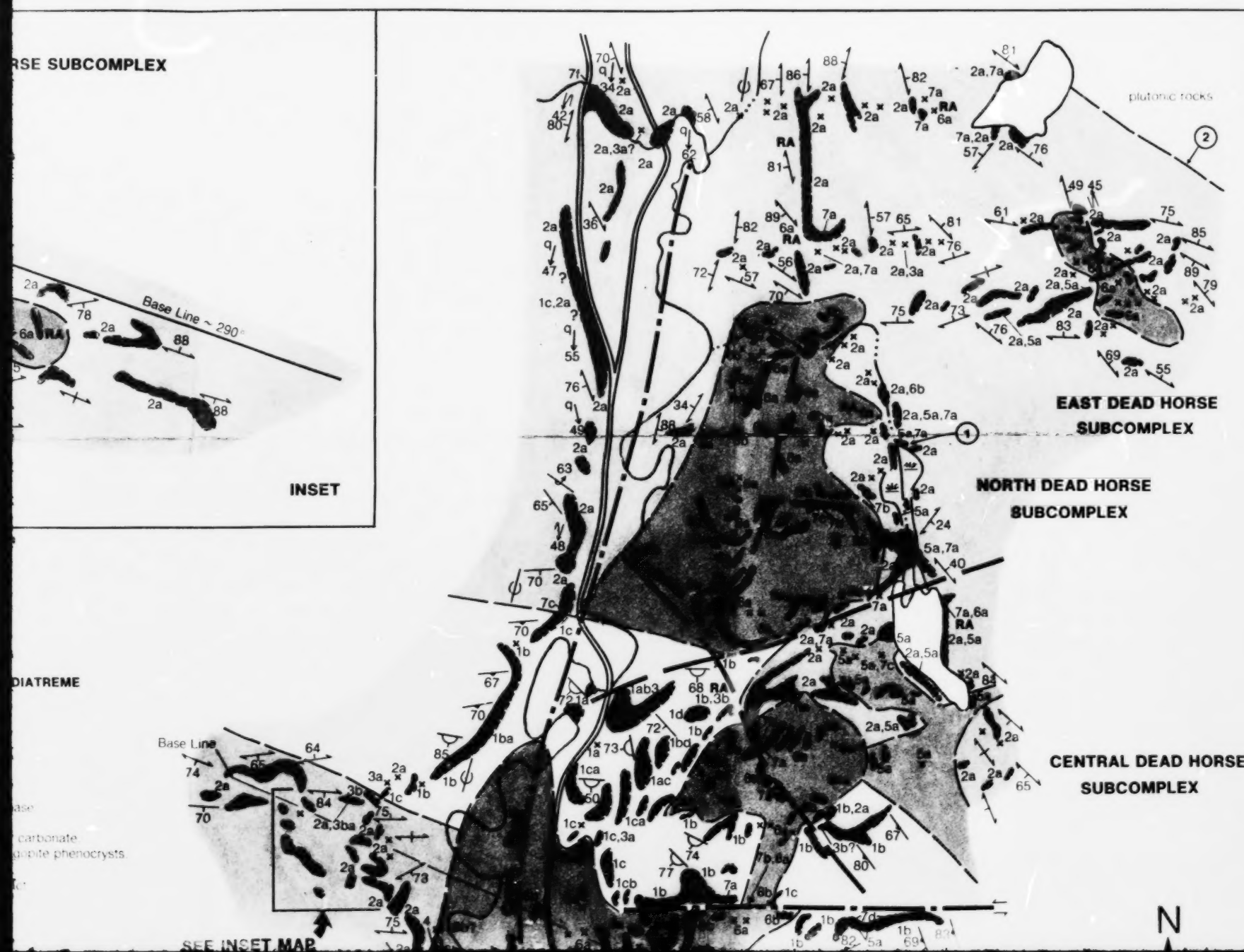
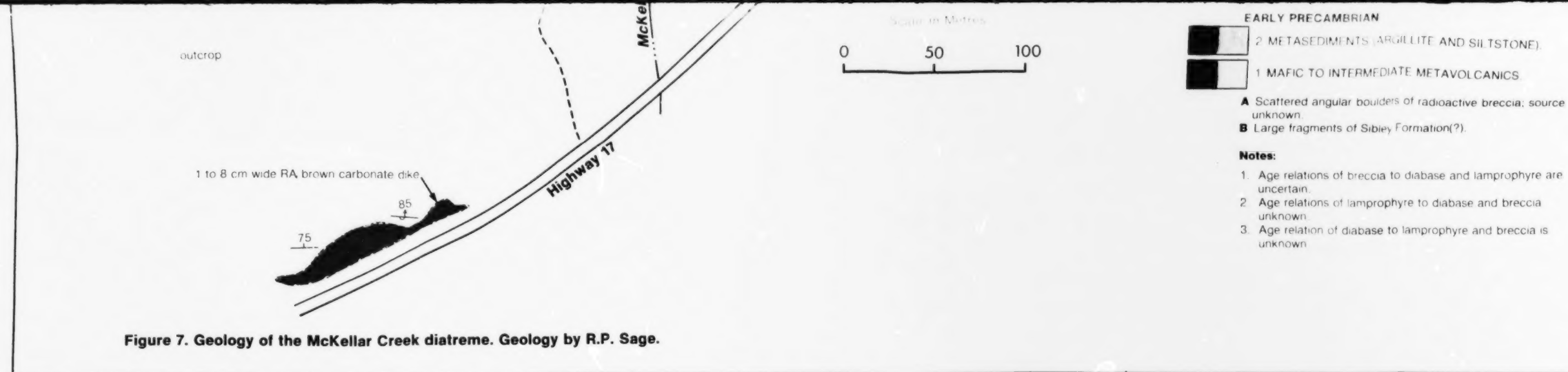
LATE PRECAMBRIAN

- DIKE ROCKS**
- 7a Diabase
 - 7b Lamprophyre
 - 7c Porphyritic (plagioclase) diabase
 - 7d Biotite syenite
 - 7e Lamprophyre, predominantly carbonate
 - 7f Lamprophyre with large phlogopite phenocrysts
- Intrusive Contact**

DIATREME BRECCIA

- 6a Strong to moderate brecciation
- 6b Moderate to weak brecciation
- 6c Weak brecciation
- 6d No brecciation





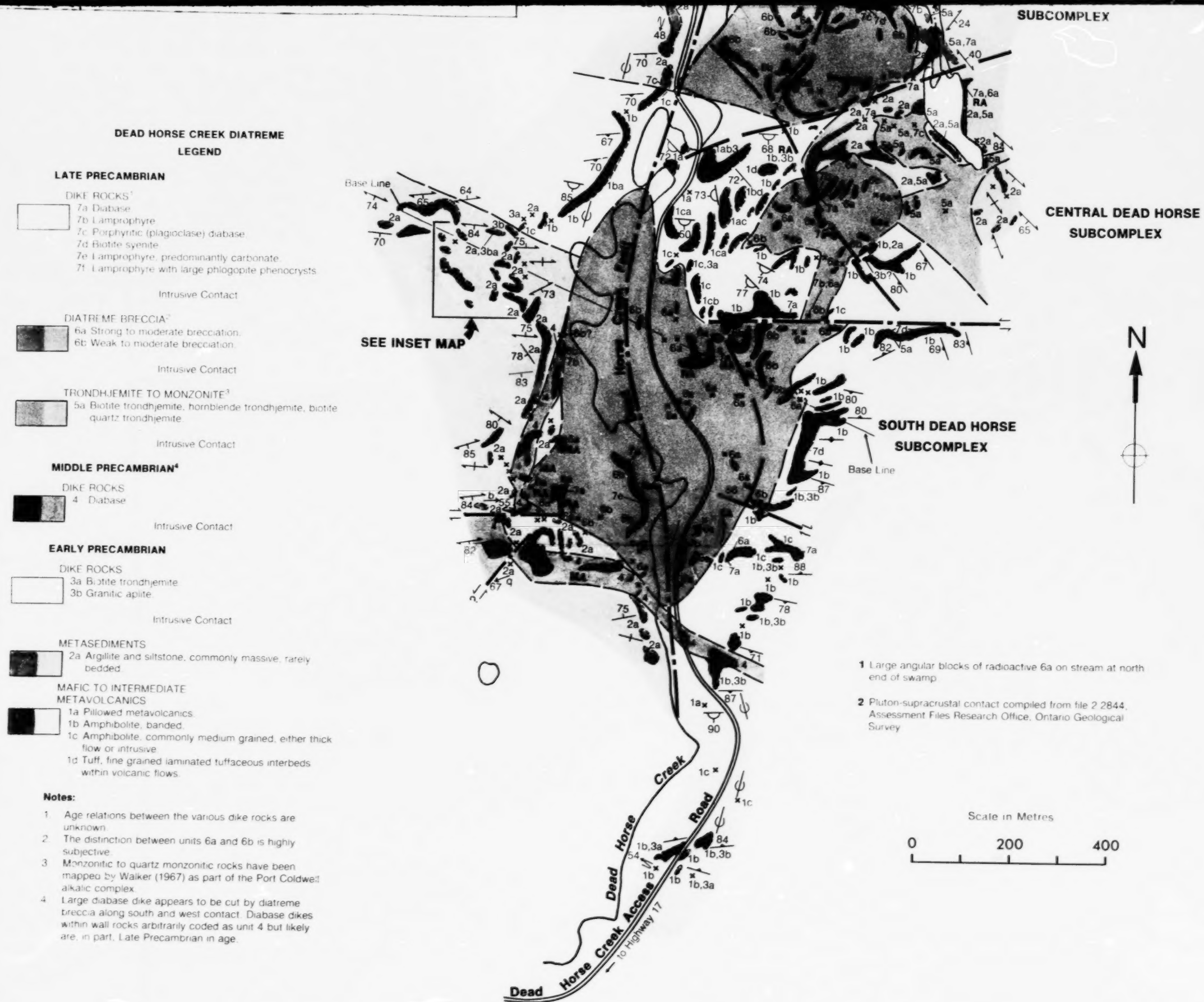
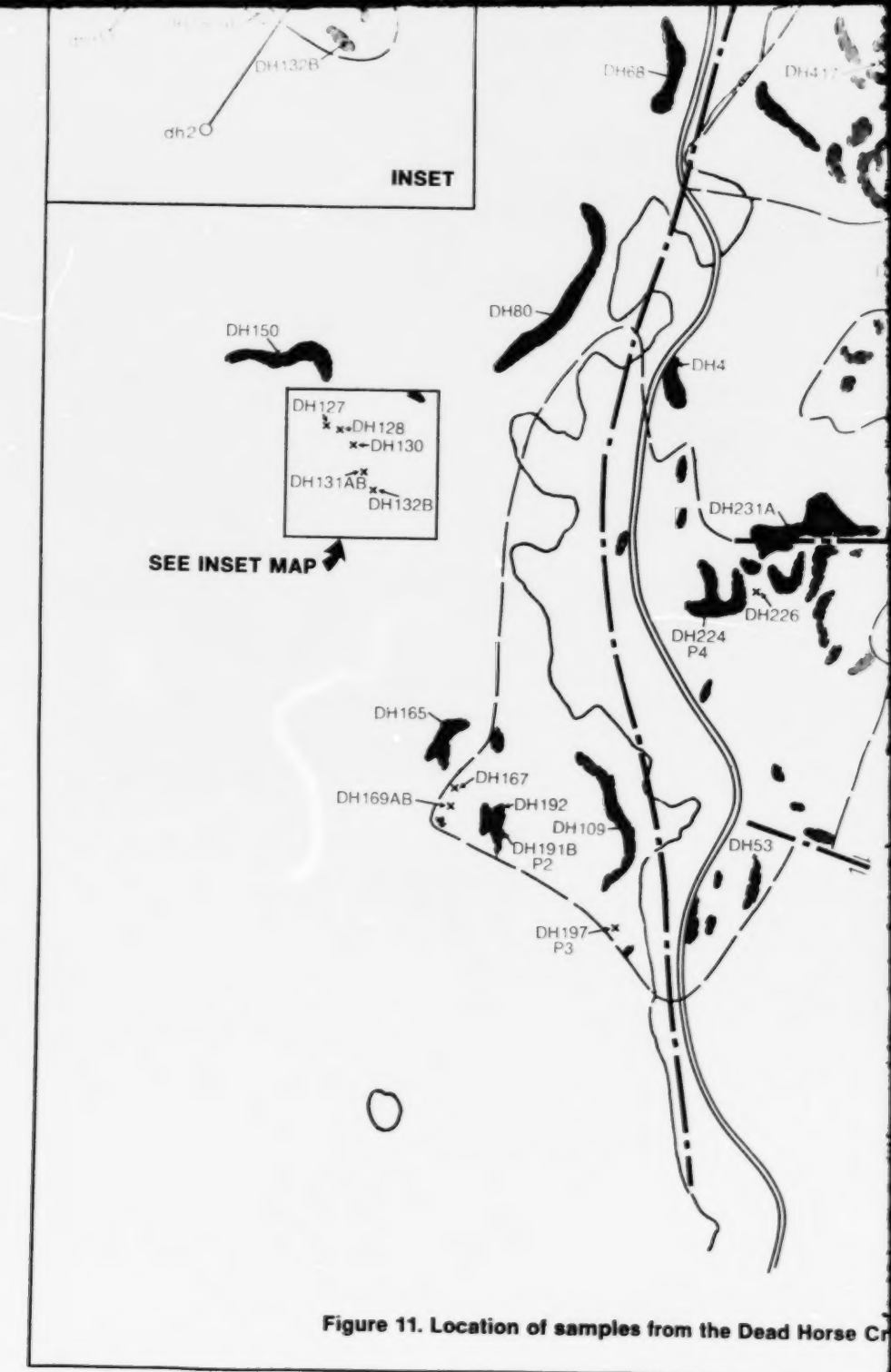


Figure 10. Geology of the Dead Horse Creek diatreme. Geology by R.P. Sage.



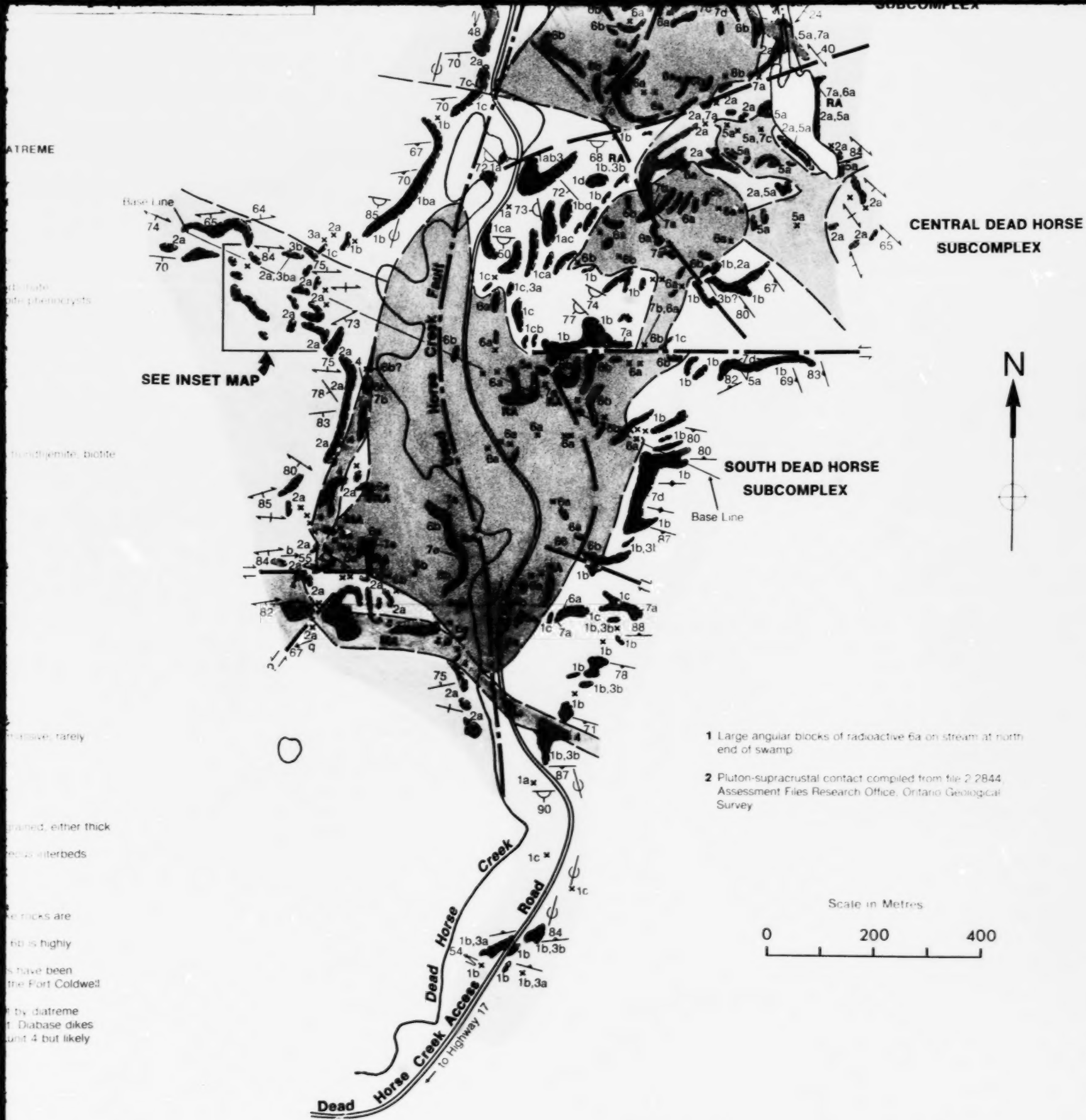


Figure 10. Geology of the Dead Horse Creek diatreme. Geology by R.P. Sage.

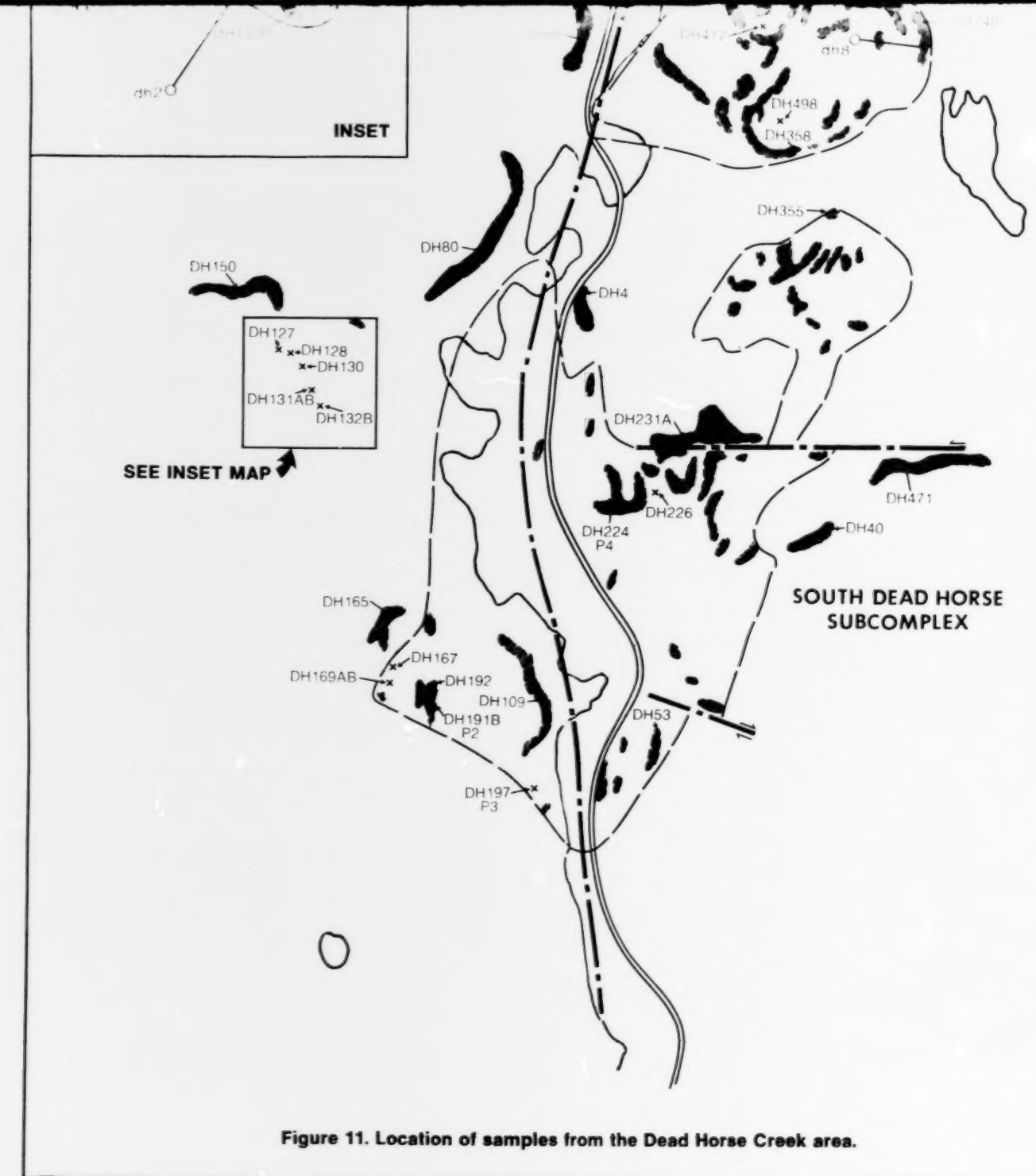


Figure 11. Location of samples from the Dead Horse Creek area.

TABLE 4. MINOR ELEMENT ANALYSES OF DIAMETRE BRECCIAS AND WALL ROCKS FROM THE SLATE ISLANDS.

		SELECTED ANALYSES																																							
Analytical Method		S1-1	S1-2	S2-1	S2-1A	S2-2	S2-2A	S3-1	S3-1A	S3-2	S3-2A	S4-1	S4-2	S5-1	S5-2	S5-3	S6-1	S6-2	S6-3	S6-4	S6-5	S6-6	S7-1	S7-2	S8-1	S8-2	S9-1	S11-1	S12-1'	S12-2	S13-1	S14-1	S15-1	S16-1	S16-2	S16-3	S16-4	S17-1'	S17-2'	S17-3'	
Ba	A	160	80	250	220	200	200	160	200	370	450	470	160	60	160	40	320	340	240	60	70	80	270	410	220	1400	280	170	260	220	600	350	220	320	300	420	360	470	240	350	
Sr	A	50	630	60	60	400	390	60	60	160	110	300	160	60	190	30	160	230	230	30	40	50	170	140	220	400	240	140	280	300	260	160	110	160	290	170	180	110	290	70	
P		620	1000	1500	1300	2280	2360	1380	1260	1160	1680	500	1680	600	1160	800	720	920	1360	600	700	480	2160	1160	1920	3400	1400	1600	3000	5520	1360	1400	1080	1400	1360	2000	1760	1040	1480	1160	
TiO ₂ (%)	C	0.43	0.42	0.40	0.50	2.61	2.50	0.50	0.43	0.41	0.32	0.62	1.35	0.14	1.51	0.31	0.44	0.32	0.32	0.21	0.43	0.32	0.32	0.30	0.50	0.23	0.81	0.76	0.24	0.20	0.20	0.54	0.11	0.14	0.23	0.76	0.40	0.81	0.30	0.71	
SUPPLEMENTARY ANALYSES FOR LARGEST DIATREME ON SLATE (10-11)																																									

SUPPLEMENTARY ANALYSES FOR LARGEST DIATREME ON SLATE ISLANDS

Analytical Method		Detect. Limit	S6-1	S6-2	S6-3	S6-4	S6-5	S6-6
Ba	S	200	*	*	*	*	*	*
Be	S	1	*	*	*	*	*	*
Ce	S	10	30	30	*	20	20	20
Co	A	5	11	6	8	12	24	23
Cr	A	5	29	*	*	53	173	191
Cu	A	5	28	6	24	10	21	50
Eu	S	100	*	*	*	*	*	*
La	S	100	*	*	*	*	*	*
Li	A	3	18	10	26	6	10	10
Mo	S	1	*	*	*	6	5	5
Na ₂ O(%)	X		3.57	2.29	2.88	0.39	0.50	0.56
Nb	S	30	*	*	*	*	*	*
Ni	A	5	28	5	32	23	87	86
Pb	A	10	*	10	*	*	22	18
Sc	S	5	7	*	9	*	8	10
Th	X	10	*	*	*	*	*	*
U ₃ O ₈	F	1	*	*	*	*	*	1
V	S	10	60	25	60	50	70	80
Yb	S	1	*	*	*	2	2	2
Zn	S	5	50	18	62	34	97	57
Zr	S	10	150	150	200	100	100	100

SAMPLES (SEE FIGURE 5 FOR LOCATIONS)

- S1-1 Grey breccia dike.
- S1-2 Felsic metavolcanic wall rock.
- S2-1 Breccia dike cutting Late Precambrian mafic flow.
- S2-1A Same as above.
- S2-2 Late Precambrian mafic flow; non-amygdaloidal; shatter coned.
- S2-2A Same as above.
- S3-1 Breccia.
- S3-1A Breccia.
- S3-2 Felsic metavolcanic.
- S3-2A Felsic metavolcanic.
- S4-1 Breccia with diabase matrix.
- S4-2 Diabase sill beneath breccia.
- S5-1 Breccia dike at Lake Precambrian-Middle Precambrian unconformity.
- S5-2 Late Precambrian mafic flow.
- S5-3 Gunflint Formation, argillite portion.
- S6-1 Felsic metavolcanic flow breccia.
- S6-2 Same as above.
- S6-3 Same as above.
- S6-4 Breccia in bush behind beach.
- S6-5 Breccia at beach level.
- S6-6 Breccia at wave base.
- S7-1 Breccia dike.
- S7-2 Sericite schist wall rock.
- S8-1 Breccia dike with clast.
- S8-2 Felsic metavolcanic.
- S9-1 Sericite schist wall rock on east shore of Dupis Island.
- S11-1 Fractured and altered diatreme dike 200 feet north of diatreme.
- S12-1 Breccia on shoal.
- S12-2 Same as above.
- S13-1 Sericite schist 600 feet east of diatreme.
- S14-1 Breccia dike cutting felsic metavolcanic at beach level.
- S15-1 Felsic metavolcanic, flow breccia.
- S16-1 Felsic metavolcanic sericite schist.
- S16-2 Same as above.
- S16-3 Breccia matrix marginal to large clast.
- S16-4 Breccia dike cutting felsic metavolcanic.
- S17-1 Breccia, dominantly argillite.
- S17-2 Same as above.
- S17-3 Same as above.
- † Wall rock to breccia dike not exposed.

METHOD

- (Detection limits shown where relevant)
- A— Atomic absorption
- C— Chemical
- F— UV fluorescence
- S— Spectrographic
- X— X-ray fluorescence

NOTES

Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.
All analyses in ppm except as noted.
* Not detected.

TABLE 7. CHEMICAL ANALYSES OF DIATREME BRECCIA AND WALL ROCK

		BRECCIA						WALL ROCK (M)		
Major Elements ¹		MC22B	MC23	MC27	MC3	MC38	AVE	MC39	MC78	MC79
SiO ₂	I	55.4	60.4	52.4	46.4	47.4	52.4	60.8	60.2	58.4
Fe ₂ O ₃	I	2.45	2.08	2.35	2.32	4.38	2.76	0.64	1.09	1.4
FeO	I	4.29	3.32	3.89	4.88	5.35	4.35	4.13	3.56	4.3
Na ₂ O	X	3.49	4.14	2.15	0.28	1.56		5.18	4.34	5.3
K ₂ O	I	0.77	1.52	3.42	4.78	3.66	2.83	0.29	0.24	0.3
TiO ₂	C	0.22	0.08	0.88	0.78	1.02		0.40	1.00	0.8
P ₂ O ₅	C	0.40	0.45	0.50	0.43	0.77		0.22	0.18	0.3
FeO/Fe ₂ O ₃						1.58				

Minor Elements¹

Ba	S(200)	320	1300	3200	2200	1600		630	620	8
Be	E(1)	5	5	4	4	8		*	*	*
Co	A(5)	13	20	16	16	20		20	19	1
Cr	A(5)	288	273	216	198	210		199	19	1
Cu	A(5)	24	76	46	36	32		48	48	1
Li	A(3)	10	6	6	6	16		21	24	1
Mo	E(1)	2	1	*	4	9		*	*	*
Nb	S(30)	350	300	400	350	300		*	*	*
Ni	A(5)	50	46	36	37	53		60	69	1
Pb	A(10)	38	19	18	27	201		22	18	1
Sc	E(5)	15	15	15	15	20		15	15	1
Sr	E(10)	450	300	700	1000	1500		500	600	1
V	E(10)	150	150	150	150	250		90	90	1
Y	E(10)	70	50	150	200	150		15	*	1
Zn	A(5)	73	63	160	90	2120		82	74	1
Zr	E(10)	45	90	100	60	70		20	200	1

Radioactive Elements¹

Th	X(10)	70	40	70	180	140		20	*	*
U ₃ O ₈	F(1)	21	36	13	24	38		*	*	*

REE¹

La	E(100)	200	100	250	400	300		*	*	*
Ce	X(10)	300	210	350	550	540		80	60	1
Nd	E(100)	150	100	150	300	200		40	60	1
Yb	E(1)	3	2	10	15	10		*	*	*

TABLE 9. CHEMICAL ANALYSES OF DIATREME BRECCIA AND WALL ROCKS FROM THE DEAD HORSE CREEK AREA.

Major Elements ¹		RED BRECCIA																SCAPOLITE- REPLACED BRECCIA		CARBONATE-RICH BRECCIA					WEST SUBCOMPLEX HIGH-GRADE SAMPLES					MISCELLANEOUS BRECCIA AND DIKE SAMPLES												
		DH132	DH132B	DH167	DH191B	DH231A	DH355	DH358	DH388	DH393	DH403C	DH406	DH409B	DH414	DH417	DH429	DH485	DH498	DH224	DH443	DH169A	DH169B	DH197	DH197	DH386	AVE	DH127	DH128	DH130	DH131A	DH131A	DH53	DH109	DH192	DH226	DH471	DH474B	DH482B	DH4	DH40	DH6	
SiO ₂	I	74.5	52.8	51.0	44.2	48.6	46.6	47.8	36.0	54.6	52.6	54.0	53.8	53.6	28.2	28.2	47.6	51.2	38.4	55.4	32.6	29.0	28.4		20.0	44.7																
Fe ₂ O ₃	I	3.80	3.24	3.52	2.81	2.72	4.81	2.00	6.59	1.72	3.33	1.63	3.51	6.57	5.86	12.10	3.20	2.28	5.79	2.45	3.88	4.10	2.25		5.40	4.07																
FeO	I	4.54	2.59	4.13	4.29	7.45	5.75	5.99	7.05	4.29	4.13	5.51	1.54	0.89	3.48	4.05	4.13	6.08	5.51	7.53	4.78	5.59	3.65		7.29	4.79																
Na ₂ O	X	1.56	0.87	0.56	1.44	0.82	1.58	4.30	0.95	3.99	3.58	4.01	0.73	5.52	1.71	0.89	3.22	3.58	0.95	2.86	0.69	0.90	0.68		0.83																	
K ₂ O	I	0.12	8.63	5.21	5.88	2.05	6.46	2.75	5.78	4.03	5.21	3.33	9.11	4.63	4.39	1.49	5.42	4.03	5.02	2.02	3.71	2.51	5.52		1.86																	
TiO ₂	C	11.3	0.55	0.39	0.12	0.16	0.56	0.20	1.00	0.16	0.28	0.34	0.16	0.36	5.60	9.60	0.30	0.34	0.62	1.48	5.60	1.35	3.60		2.46		1.43	4.78	4.18	1.81	4.95		5.46	0.73	0.86	2.59	5.64	5.99	5.69			
P ₂ O ₅	C	0.10	0.58	0.88	1.07	0.75	1.55	1.00	1.83	0.48	0.60	0.58	0.56	0.17	0.68	0.40	0.26	0.85	0.62	0.50	1.45	1.31	0.52		1.87		0.37	1.47	0.74	0.04	0.03		1.26	11.7	1.96	0.22	0.48	0.48	0.18			
FeO/Fe ₂ O ₃																											0.10	0.71	0.73	0.71	0.31		0.40	0.18	2.10	0.85	0.20	0.22	0.22	0.08	0.10	0.14
Minor Elements ¹																																										
Ba	S(200)	500	1500	5500	7000	2000	1000	1000	4000	1500	1500	900	9000	4000	1500	500	4000	5000	2500	600	4000	2000	700		1000																	
Be	S(1)	35	15	10	10	15	15	9	15	8	10	8	5	20	8	15	10	10	7	15	7	8																				
Co	A(5)	10	18	22	28	45	46	29	39	26	24	27	32	*	19	15	28	28	56	19	24	29	15		55		200	1000	600	5000	1.1%	1500	*	1000	1500	*	*	250	130	1100	600	
Cr	A(5)	159	231	277	213	480	177	146	550	269	235	270	283	85	88	112	216	144	550	208	247	234	169		395		15	1.0%**	600	4500	4600											
Cu	A(5)	8	44	44	76	72	60	48	89	60	42	68	69	10	54	38	60	46	124	49	80	104	48		95		9	8	9	*	*											
Li	A(3)	22	20	16	11	28	18	30	32	14	20	26																														
Mo	S(1)	6	7	4	7	15	13	10	1	3	*	5	15	*	*	25	5	18	88	32	26	29	14		42		53	9	7	10	6											
Nb	S(30)	70	50	90	*	80	200	300	150	80	150	35	1000	200	350	5	*	*	25	5	4	7	3		50		74	58	1580	240	64											
Si	A(5)	24	51	66	64	72	86	63	230	83	69	79	70	200	350	500	250	100	250	250	100	100	200		200		20	15	*	2	*											
Al	A(10)	279	88	110	83	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110		110																		

RECCIAS AND WALL ROCKS FROM THE SLATE ISLANDS.

SELECTED ANALYSES

S3-1A	S3-2	S3-2A	S4-1	S4-2	S5-1	S5-2	S5-3	S6-1	S6-2	S6-3	S6-4	S6-5	S6-6	S7-1	S7-2	S8-1	S8-2	S9-1	S11-1	S12-1'	S12-2	S13-1	S14-1	S15-1	S16-1	S16-2	S16-3	S16-4	S17-1'	S17-2'	S17-3'
200	370	450	470	160	60	160	40	320	340	240	60	70	80	270	410	220	1400	280	170	260	220	600	350	220	320	300	420	360	470	240	350
60	160	110	300	160	60	190	30	160	230	230	30	40	50	170	140	220	400	240	140	280	300	260	160	110	160	290	170	180	110	290	70
1260	1160	1680	500	1680	600	1160	800	720	920	1360	600	700	480	2160	1160	1920	3400	1400	1600	3000	5520	1360	1400	1080	1400	1360	2000	1760	1040	1480	1160
0.43	0.41	0.32	0.62	1.35	0.14	1.51	0.31	0.44	0.32	0.32	0.21	0.43	0.32	0.32	0.30	0.50	0.23	0.81	0.76	0.24	0.20	0.20	0.54	0.11	0.14	0.23	0.76	0.40	0.81	0.30	0.71

LARGEST DIATREME ON SLATE ISLANDS

SAMPLES (SEE FIGURE 5 FOR LOCATIONS)

- S1-1 Grey breccia dike.
S1-2 Felsic metavolcanic wall rock.
S2-1 Breccia dike cutting Late Precambrian mafic flow.
S2-1A Same as above.
S2-2 Late Precambrian mafic flow; non-amygdaloidal; shatter coned.
S2-2A Same as above.
S3-1 Breccia.
S3-1A Breccia.
S3-2 Felsic metavolcanic.
S3-2A Felsic metavolcanic.
S4-1 Breccia with diabase matrix.
S4-2 Diabase sill beneath breccia.
S5-1 Breccia dike at Lake Precambrian-Middle Precambrian unconformity.
S5-2 Late Precambrian mafic flow.
S5-3 Gunflint Formation, argillite portion.
S6-1 Felsic metavolcanic flow breccia.
S6-2 Same as above.
S6-3 Same as above.
S6-4 Breccia in bush behind beach.
S6-5 Breccia at beach level.
S6-6 Breccia at wave base.
S7-1 Breccia dike.
S7-2 Sericite schist wall rock.
S8-1 Breccia dike with clast.
S8-2 Felsic metavolcanic.
S9-1 Sericite schist wall rock on east shore of Dupis Island.
S11-1 Fractured and altered diatreme dike 200 feet north of diatreme.
S11-2 Breccia on shoal.
S12-2 Same as above.
S13-1 Sericite schist 600 feet east of diatreme.
S14-1 Breccia dike cutting felsic metavolcanic at beach level.
S15-1 Felsic metavolcanic, flow breccia.
S16-1 Felsic metavolcanic sericite schist.
S16-2 Same as above.
S16-3 Breccia matrix marginal to large clast.
S16-4 Breccia dike cutting felsic metavolcanic.
S17-1 Breccia, dominantly argillite.
S17-2 Same as above.
S17-3 Same as above.
† Wall rock to breccia dike not exposed.

METHOD

(Detection limits shown where relevant)

- A— Atomic absorption
C— Chemical
F— UV fluorescence
S— Spectrographic
X— X-ray fluorescence

NOTES

Analyses by Geoscience Laboratories,
Ontario Geological Survey, Toronto

All analyses in ppm except as noted.

* Not detected.

TABLE 7. CHEMICAL ANALYSES OF DIATREME BRECCIA AND WALL ROCKS FROM THE MCKELLAR CREEK AREA.

BRECCIA							WALL ROCK (METASEDIMENTS)					METHOD (Detection limits shown in parenthesis where relevant) I — Inductively coupled plasma. X — X-ray fluorescence. C — Chemical. S — Spectrographic. E — Emission. A — Atomic absorption. F — UV fluorescence.
Major Elements ¹		MC22B	MC23	MC27	MC38	MC29	AVE	MC59	MC78	MC97	MC112	
SiO ₂	I	55.4	60.4	52.4	46.4	47.4	52.4	60.8	60.2	58.8	59.2	59.8
Fe ₂ O ₃	I	2.45	2.08	2.35	2.52	4.38	2.76	0.64	1.09	1.18	0.82	0.93
FeO	I	4.29	3.32	3.89	4.86	5.35	4.35	4.13	3.56	4.94	5.10	0.14
Na ₂ O	X	3.49	4.14	2.15	0.23	1.56		5.18	4.34	5.18	5.74	
K ₂ O	I	0.77	1.52	3.42	4.75	3.66	2.83	0.29	0.24	0.39	0.14	0.27
TiO ₂	C	0.22	0.08	0.88	0.78	1.02		0.40	1.00	0.39	0.40	
P ₂ O ₅	C	0.40	0.45	0.50	0.43	0.77		0.22	0.18	0.22	0.02	
FeO/Fe ₂ O ₃							1.58					
Minor Elements¹												
Ba	S(200)	320	1300	3200	2200	1600		630	620	850	260	
Be	E(1)	5	5	4	4	8		*	*	*	*	
Co	A(5)	13	20	16	16	20		20	19	21	19	
Cr	A(5)	288	273	216	198	210		199	19	199	239	
Cu	A(5)	24	76	46	36	32		48	48	38	30	
Li	A(3)	10	6	6	6	16		21	24	22	21	
Mo	E(1)	2	1	*	4	9		*	*	*	*	
Nb	S(30)	350	300	400	350	300		*	*	*	*	
Ni	A(5)	50	46	36	37	53		60	69	70	90	
Pb	A(10)	38	19	18	27	201		22	18	21	*	
Sc	E(5)	15	15	15	15	20		15	15	15	15	
Sr	E(10)	450	300	700	1000	1500		500	600	350	200	
V	E(10)	150	150	150	150	250		90	90	150	100	
Y	E(10)	70	50	150	200	150		15	*	20	*	
Zn	A(5)	73	63	160	90	2120		82	74	86	50	
Zr	E(10)	45	90	100	60	70		20	200	150	200	
Radioactive Elements¹												
Th	X(10)	70	40	70	180	140		20	*	10	10	
U ₃ O ₈	F(1)	21	36	13	24	38		*	*	*	*	
REE¹												
La	E(100)	200	100	250	400	300		*	*	*	*	
Ce	X(10)	300	210	350	550	540		80	60	60	80	
Nd	E(100)	150	100	150	300	200		40	60	30	50	
Yb	E(1)	3	2	10	15	10		*	*	*	*	

METHOD
(Detection limits shown where relevant)
A— Atomic absorption
C— Chemical
F— UV fluorescence
S— Spectrographic
X— X-ray fluorescence
NOTES
Analyses by Geoscience Laboratories,
Ontario Geological Survey, Toronto
All analyses in ppm except as noted.
* Not detected.

TABLE 9. CHEMICAL ANALYSES OF DIATREME BRECCIA AND WALL ROCKS FROM THE DEAD HORSE CREEK AREA.

Major Elements ¹		RED BRECCIA																			SCAPOLITE- REPLACED BRECCIA		CARBONATE-RICH BRECCIA				WEST SUBCOMPLEX HIGH-GRADE SAMPLES					MISCELLANEOUS BRECCIA AND DIKE SAMPLES										
		DH132	DH132B	DH167	DH191B	DH231A	DH355	DH358	DH388	DH393	DH403C	DH406	DH409B	DH414	DH417	DH429	DH485	DH498	DH224	DH443	DH169A	DH169B	DH197	DH197	DH386	AVE	DH127	DH128	DH130	DH131A	DH131A	DH53	DH109	DH192	DH226	DH471	DH474B	DH482B	DH4	DH40	DH68	
SiO ₂	I	74.5	52.8	51.0	44.2	48.6	46.6	47.8	36.0	54.6	52.6	54.0	53.8	53.6	28.2	28.2	47.6	51.2	38.4	55.4	32.6	29.0	28.4		20.0	44.7																
Fe ₂ O ₃	I	3.80	3.24	3.52	2.81	2.72	4.81	2.00	6.59	1.72	3.33	1.63	3.51	6.57	5.86	12.10	3.20	2.28	5.79	2.45	3.88	4.10	2.25		5.40	4.07																
FeO	I	4.54	2.59	4.13	4.29	7.45	5.75	5.99	7.05	4.29	4.13	5.51	1.54	0.89	3.48	4.05	4.13	6.08	5.51	7.53	4.78	5.59	3.65		7.29	4.79																
Na ₂ O	X	1.56	0.87	0.56	1.44	0.82	1.58	4.30	0.95	3.99	3.58	4.01	0.73	5.52	1.71	0.89	3.22	3.58	0.95	2.86	0.69	0.90	0.68		0.83		1.43	4.78	4.18	1.81	4.95		5.46	0.73	0.86	2.59	5.64	5.99	5.69			
K ₂ O	I	0.12	8.63	5.21	5.88	2.05	6.46	2.75	5.78	4.03	5.21	3.33	9.11	4.63	4.39	1.49	5.42	4.03	5.02	2.02	3.71	2.51	5.52		1.86	4.18																
TiO ₂	C	11.3	0.55	0.39	0.12	0.16	0.56	0.20	1.00	0.16	0.28	0.34	0.16	0.36	5.60	9.60	0.30	0.34	0.62	1.48	5.60	1.35	3.60		2.46		0.37	1.47	0.74	0.04	0.03		1.26	11.7	1.96	0.22	0.48	0.48	0.18			
P ₂ O ₅	C	0.10	0.58	0.88	1.07	0.75	1.55	1.00	1.83	0.48	0.60	0.58	0.56	0.17	0.68	0.40	0.26	0.85	0.62	0.50	1.45	1.31	0.52		1.87		0.10	0.71	0.73	0.71	0.31		0.40	0.18	2.10	0.85	0.20	0.22	0.22			
FeO/Fe ₂ O ₃																									1.18																	
Minor Elements ¹																																										
Ba	S(200)	500	1500	5500	7000	2000	1000	1000	4000	1500	1500	900	9000	4000	1500	500	4000	5000	2500	600	4000	2000	700		1000		200	1000	600	5000	1.1%	1500	*	1000	1500	*	*	250	130	1100	600	
Be	S(1)	35	15	10	10	15	15	9	15	8	10	8	5	20	8	15	10	10	7	15	7	8	*		10		15	1.0%**	1.0%**	4500	4600	1500	6	9	6	4	20	20	7	*	5	3
Co	A(5)	10	18	22	28	45	46	29	39	26	24	27	32	*	19	15	28	28	56	19	24	29	15		55		9	8	9	*	5	19	40	43	12	*	*	*	39	46	29	
Cr	A(5)	159	231	277	213	480	177	146	550	269	235	270	283	85	88	112	216	144	550	208	247	234	169		395		440	670	1560	920	900	212	251	105	430	159	155	243	308	420	232	
Cu	A(5)	8	44	44	76	72	60	48	89	60	42	68	69	10	54	38	60	46	124	49	80	104	48		95		53	9	7	10	6	20	16	122	46	24	6	55	61	42	65	
Li	A(3)	22	20	16	11	28	18	30	32	14	20	26	10	98	29	12	21	18	88	32	26	29	14		42		74	58	1580	240	64	9	10	12	23	6	8	3	31	34	54	
Mo	S(1)	6	7	4	7	15	13	10	1	3	*	5	15	*	*	25	5	*	25	5	4	7	3		50		20	15	*	2	1	25	15	5	5	4	5	7	*	*	*	
Nb	S(30)	70	50	90	*	80	200	300	150	80	150	35	1000	200	350	500	250	100	250	250	100	100	200	350	200		250	?	?	35	70	100	45	100	300	500	600	500	*	*	*	
Ni	A(5)	24	51	66	64	72	86	63	230	83	69	79	70	*	29	13	60	64	141	41	73	102	47		178		21	22	39	16	13	24	39	48	53	*	*	*	76	144	118	
Pb	A(10)	270	62	38	23	34	26	37	60	144	42	55	16	37	147	128	72	32	51	46	58	75	64		25		35	590	126	114	109	105	108	320	68	18	45	35	*	*	*	
Sc	S(5)	40	15	20	25	45	35	25	20	15	20	15	10	*	20	35	20	25	30	25	15	10	15		20		*	0.1%**	700	150	250	15	40	25	25	*	*	*	17	68	24	
Sr	S(10)	2500	600	500	600	400	450	500	3000	500	600	400	600	450	3000	0.1%***	500	450	800	600	1000	900	1500	4600	4000		25	800	700	300	300	700	450	1500	1000	900	60	30	20	200	600	200
V	E(10)	100	150	200	150	300	200	200	250	100	150	150	80	*	150	300	200	150	150	150	100	80	150	200	150		70	1000	1500	900	450	90	100	200	150	*	*	*	350	250	200	
Y	E(10)	*	90	80	70	70	150	50	60	35	70	20	90	50	600	1000	70	60	450	200	800	250	450	300	60		450	0.1%**	400	90	350	100	0.1%**	600	450	100	70	90	25	30	20	
Zn	A(5)	300	74	84	52	120	260	140	690	200	160	140	92	200	250	420	160	120	170	310	420	170		170		16	30	52	42	16	120	150	450	1310	60	94	160	99	112	52		
Zr	S(10)	3000	250	200	100	150	250	150	200	150	200	150	200	800	1000	900	200	100	200	1000	800	800	500	600		600		250	3.0%**	3.0%**	8000	3.0%**	250	2500	500	2000	1000	1500	1500	90	80	150
Radioactive Elements ¹																																										
Th	X(10)	790	100	100	50	10	50	40	30	*	40	20	20	80	490	390	20	40	250	290	230	220	180		50		520	4770	1210	500	1530	200	750	150	650	110	90	110	*	*	*	
U ₃ O ₈	F(1)	100	29	35	20	*	9	*	12	2	15	4	12	16	410	390	12	40	38	110	35	32	46		8		35	6800	3300	310	1250	6	240	31	650	25	10	20	2	*	*	
REE ¹																																										
La	S(100)	1000	200	900	900	*	*	*	100	*	250	*	100	300	500	700	*	*	400	600	1500	2500	900	800	250		*	*	*	*	*	250	5500	1500	600	150	300	300	*	*	*	
Ce	S(10)	1500	0.1%***	1500	1000	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	1000	1500	0.1%***	0.1%***	1000	1000	2000	3000	1500	1140	0.1%***		0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***
Nd	S(100)	1500	150	600	350	*	*	*	*	*	200	*	*	*	800	1000	*	*	450	800	2000	3000	1500	1000	450		*	3000	700	250	800	200	5000	2000	1500	1500	0.1%***	0.1%***	0.1%***	40	60	*
Eu	S(100)	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	
Yb	S(1)	100	6	7	5	5	10	3	5	2	3	1	3	4	10	70	4	4	30	15	35	15	25	15	2		20	250	170	20	50	5	100	20	20	8	5	7	2	2	2	

METHOD
(Detection limits shown in parentheses where relevant)
I— Inductively coupled plasma.
X— X-ray fluorescence.
C— Chemical.
S— Spectrographic.
E— Emission.
A— Atomic absorption.
F— UV fluorescence.
NOTES
Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.
Major elements in weight percent; all others in ppm.
*Average of metasediments only.
* Not detected.
** Quantity greater than amount indicated.
*** Quantity slightly less than amount indicated.

SAMPLES
DH132 Breccia
DH132B Breccia
DH167 Breccia
DH191B Breccia
DH231A Breccia, sulphide in matrix
DH355 Breccia, sulphide in matrix
DH358 Breccia, sulphide in matrix
DH388 Breccia matrix
DH393 Breccia matrix
DH403C Breccia matrix, sulphide present
DH406 Breccia matrix, sulphide present
DH409B Breccia matrix, sulphide present
DH414 Breccia matrix, sulphide present
DH417 Breccia matrix, sulphide present
DH429 Breccia matrix, sulphide present
DH485 Breccia matrix
DH498 Breccia matrix
DH224 Scapolite replaced breccia
DH443 Scapolite replaced breccia
DH169A Carbonate rich breccia matrix
DH169B Carbonate rich breccia matrix
DH197 Carbonate rich breccia
DH197 Carbonate rich matrix
DH386 Carbonate rich breccia
DH127 Sheared rock in pit
DH128 Sheared rock in pit
DH130 Sheared rock in pit
DH131A Sheared rock in pit
DH131A Sheared rock in pit
DH53 Brecciated Early Precambrian aplite dike
DH109 Carbonate rich lamprophyre
DH192 Carbonate dike cutting red breccia
DH226 Lamprophyre
DH471 Syenite dike
DH474B Syenite dike
DH482B Syenite dike
DH4 Mafic metavolcanic
DH40 Mafic metavolcanic
DH68 Metasediment
DH80 Mafic metavolcanic
DH150 Metasediment
DH165 Metasediment
DH426 Metasediment

METHOD
(Detection limits shown where relevant)
A— Atomic absorption
C— Chemical
F— UV fluorescence
S— Spectrographic
X— X-ray fluorescence

NOTES
Analyses by Geoscience Laboratories,
Ontario Geological Survey, Toronto
All analyses in ppm except as noted.
* Not detected.

MA AND WALL ROCKS FROM THE DEAD HORSE CREEK AREA.

RED BRECCIA										SCAPOLITE-REPLACED BRECCIA				CARBONATE-RICH BRECCIA				WEST SUBCOMPLEX HIGH-GRADE SAMPLES					MISCELLANEOUS BRECCIA AND DIKE SAMPLES								WALL ROCKS									
DH355	DH358	DH388	DH393	DH403C	DH406	DH409B	DH414	DH417	DH429	DH485	DH498	DH224	DH443	DH169A	DH169B	DI 197	DH197	DH386	AVE	DH127	DH128	DH130	DH131A	DH131A	DH53	DH109	DH192	DH226	DH471	DH474B	DH482B	DH4	DH40	DH68	DH80	DH150	DH165	DH426	AVE	AVE ²
6.6	47.8	36.0	54.6	52.6	54.0	53.8	53.6	28.2	28.2	47.6	51.2	38.4	55.4	32.6	29.0	28.4		20.0	44.7													45.0	45.8	57.4	50.4	60.9	59.9	55.0	53.5	58.3
4.81	2.00	6.59	1.72	3.33	1.63	3.51	6.57	5.86	12.10	3.20	2.28	5.79	2.45	3.88	4.10	2.25		5.40	4.07												2.00	2.55	1.46	6.50	0.94	1.44	1.82	2.39	1.42	
5.75	5.99	7.05	4.29	4.13	5.51	1.54	0.89	3.48	4.05	4.13	6.08	5.51	7.53	4.78	5.59	3.65		7.29	4.79												9.72	8.42	6.48	8.91	5.35	4.05	5.35	6.90	5.25	
1.58	4.30	0.95	3.99	3.58	4.01	0.73	5.52	1.71	0.89	3.22	3.58	0.95	2.86	0.69	0.90	0.68		0.83		1.43	4.78	4.18	1.81	4.95	5.46	0.73	0.86	2.59	5.64	5.99	5.69	4.38	3.35	2.80	3.11	3.04	4.93	4.61		
6.46	2.75	5.78	4.03	5.21	3.33	9.11	4.63	4.39	1.49	5.42	4.03	5.02	2.02	3.71	2.51	5.52		1.86	4.18												0.05	0.10	0.53	0.00	0.14	0.10	2.34	0.47	0.78	
0.56	0.20	1.00	0.16	0.28	0.34	0.16	0.36	5.60	9.60	0.30	0.34	0.62	1.48	5.60	1.35	3.60		2.46		0.37	1.47	0.74	0.04	0.03	1.26	11.7	1.96	0.22	0.48	0.48	0.18	1.00	0.75	0.53	0.92	0.35	0.40	0.55		
1.55	1.00	1.83	0.48	0.60	0.58	0.56	0.17	0.68	0.40	0.26	0.85	0.62	0.50	1.45	1.31	0.52		1.87		0.10	0.71	0.73	0.71	0.31	0.40	0.18	2.10	0.85	0.20	0.22	0.22	0.08	0.10	0.14	0.16	0.12	0.18	0.06		
																			1.18																				2.94	3.70

1000	1000	4000	1500	1500	900	9000	4000	1500	500	4000	5000	2500	600	4000	2000	700		1000		200	1000	600	5000	1.1%	1500	*	1000	1500	*	*	250	130	1100	600	100	640	590	850	
15	9	15	8	10	8	5	20	8	15	10	10	7	15	7	8	*		10		15	1.0%**	1.0%**	4500	4600	6	9	6	4	20	20	7	*	5	3	*	3	3	3	
46	29	39	26	24	27	32	*	19	15	28	28	56	19	24	29	15		55		9	8	9	*	5	19	40	43	12	*	*	*	39	46	29	41	21	23	32	
177	146	550	269	235	270	283	85	88	112	216	144	550	208	247	234	169		395		440	670	1560	920	900	212	251	105	430	159	155	243	308	420	232	371	222	257	272	
60	48	89	60	42	68	69	10	54	38	60	46	124	49	80	104	48		95		53	9	7	10	6	20	16	122	46	24	55	61	42	65	76	34	48	196		
18	30	32	14	20	26	10	98	29	12	21	18	88	32	26	29	14		42		74	58	1580	240	64	9	10	12	23	6	3	31	34	54	8	58	24	32		
13	10	1	3	*	5	15	*	*	25	5	*	25	5	4	7	3	1	50		20	15	*	2	1	25	15	5	5	4	5	7	*	*	*	*	*	*		
200	300	150	80	150	35	1000	200	350	500	250	100	250	250	100	100	200	350	200		250	?	?	35	70	100	45	100	300	500	600	500	*	*	*	*	*	*	*	
86	63	230	83	69	79	70	*	29	13	60	64	141	41	73	102	47		178		21	22	39	16	13	24	39	48	53	*	*	*	76	144	118	80	74	86	130	
26	37	60	144	42	55	16	37	147	128	72	32	51	46	58	75	64		25		35	590	126	114	109	105	108	320	68	18	45	35	17	68	24	12	43	22	24	
35	25	20	15	20	15	10	*	20	35	20	25	30	25	15	10	15	15	20		*	0.1%**	700	150	250	15	40	25	25	*	*	*	40	35	25	35	15	15	25	
450	500	3000	500	800	400	600	450	3000	0.1%***	500	450	800	600	1000	900	1500	4600	4000		25	800	700	300	700	700	450	1500	1000	900	60	30	20	200	600	200	250	400	500	600
200	200	250	100	150	150	80	*	150	300	200	150	150	150	100	80	150	200	150		70	1000	1500	900	450	700	100	200	150	*	*	*	350	250	200	250	100	100	150	
150	50	60	35	70	20	90	50	600	1000	70	60	450	200	800	250	450	300	60		450	0.1%**	400	90	350	100	0.1%**	600	450	100	70	90	25	30	20	30	15	20	20	
260	140	690	200	160	140	92	200	250	420	160	120	170	310	310	420	170		170		16	30	52	42	16	120	150	450	1310	60	94	99	112	52	98	106	74	95		
250	150	250	150	200	150	200	800	1000	900	200	100	200	1000	800	800	500	600		600		250	3.0%**	3.0%**	8000	3.0%**	250	2500	500	2000	1000	1500	1500	90	80	150	100	150	150	150

50	40	30	*	40	20	20	80	490	390	20	40	250	290	230	220	180		50		520	4770	1210	500	1530	200	750	150	650	110	90	110	*	*	*	*	10	*	10	
9	*	12	2	15	4	12	16	410	390	12	2	38	110	35	32	46		8		35	6800	3300	310	1250	6	240	31	39	25	10	20	2	*	*	*	*	2	*	*

*	*	100	*	250	*	100	300	500	700	*	*	400	600	1500	2500	900	800	250		*	*	*	*	*	250	5500	1500	600	150	300	300	*	*	*	*	*	*	*
0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	1000	1500	0.1%***	0.1%***	1000	1000	2000	3000	1500	1140	0.1%***		0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	0.1%***	6000	2000	1500	0.1%***	0.1%***	0.1%***	40	60	*	*	80	80	80
*	*	*	*	200	*	*	*	800	1000	*	*	450	800	2000	1500	1000	700	450		*	3000	700	250	800	200	5000	900	1500	200	250	300	*	*	*	*	*	*	*
10	3	5	2	3	1	3	4	10	70	4	4	30	15	35	15	25	15	2		20	250	170	20	50	5	100	20	20	8	5	7	2	2	2	3	*	*	1

SAMPLES		DH197 Carbonate rich breccia	
DH132	Breccia	DH197	Carbonate rich matrix
DH132B	Breccia	DH386	Carbonate rich breccia
DH167	Breccia	DH127	Sheared rock in pit
DH191B	Breccia	DH128	Sheared rock in pit
DH231A	Breccia, sulphide in matrix	DH130	Sheared rock in pit
DH355	Breccia, sulphide in matrix	DH131A	Sheared rock in pit
DH358	Breccia, sulphide in matrix	DH131A	Sheared rock in pit
DH388	Breccia matrix	DH53	Brecciated Early Precambrian aplite dike
DH393	Breccia matrix	DH109	Carbonate rich lamprophyre
DH403C	Breccia matrix, sulphide present	DH192	Carbonate dike cutting red breccia
DH406	Breccia matrix, sulphide present	DH226	Lamprophyre
DH409B	Breccia matrix, sulphide present	DH471	Syenite dike
DH414	Breccia matrix, sulphide present	DH474B	Syenite dike
DH417	Breccia matrix, sulphide present	DH482B	Syenite dike
DH429	Breccia matrix, sulphide present	DH4	Mafic metavolcanic
DH485	Breccia matrix	DH40	Mafic metavolcanic
DH498	Breccia matrix	DH68	Metasediment
DH224	Scapolite replaced breccia	DH80	Mafic metavolcanic
DH443	Scapolite replaced breccia	DH150	Metasediment
DH169A	Carbonate rich breccia matrix	DH165	Metasediment
DH169B	Carbonate rich breccia matrix	DH426	Metasediment